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Waterways Experiment Station

Ship Navigation Simulation Study, Southwest Pass Entrance, Mississippi River

by Carl J. Huval, J. Christopher Hewlett, Randy A. McCollum

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Prepared for U.S. Army Engineer District, New Orleans

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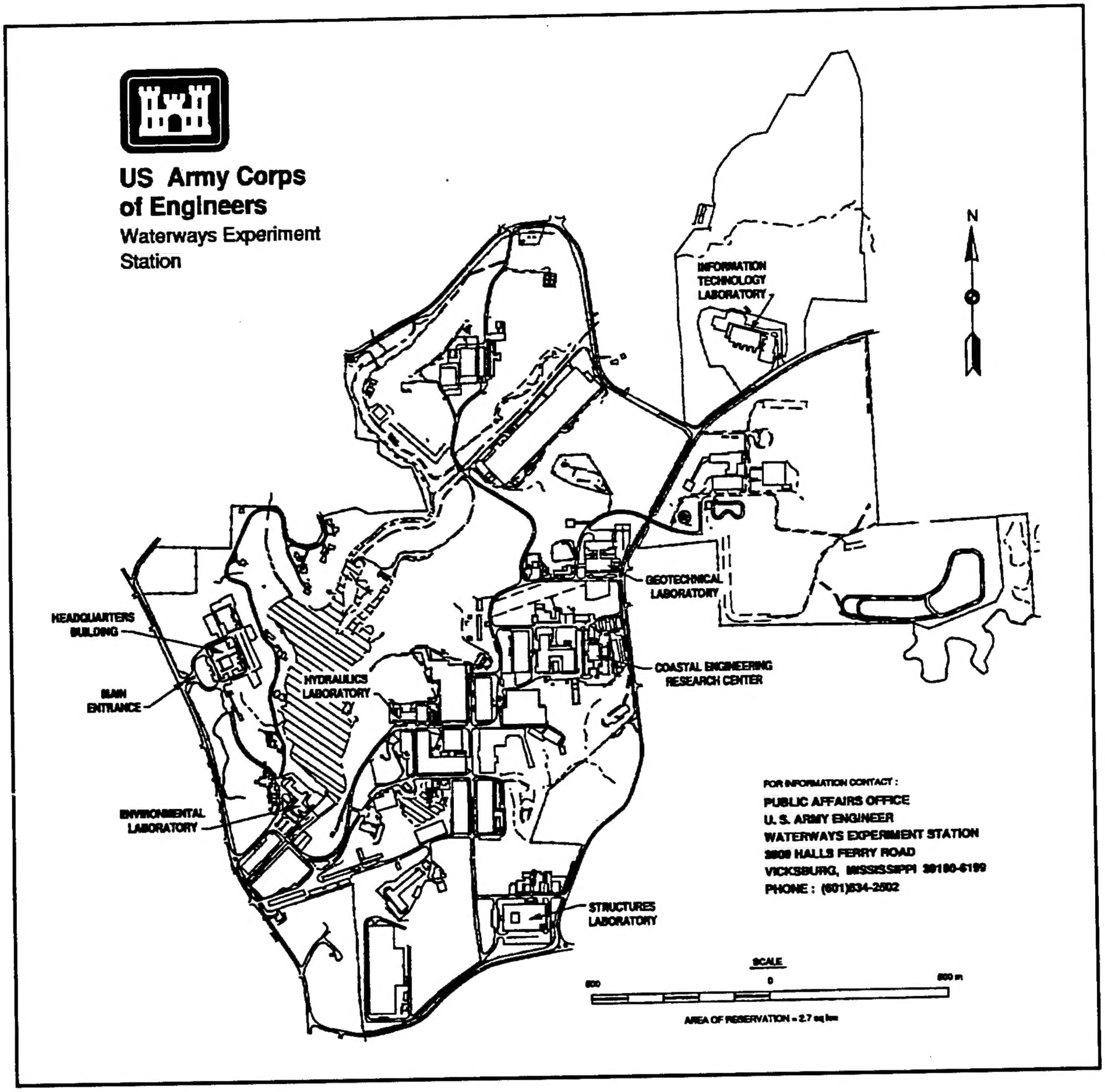

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Contents

Preface

This investigation was conducted for the U.S. Army Engineer District, New Orleans, by the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. The study was conducted in the Hydraulics Laboratory from May 1986 to April 1987.

The model study was conducted under the general supervision of Messrs. F. A. Herrmann, Jr., Director of the Hydraulics Laboratory; and R. A. Sager, Assistant Director of the Hydraulics Laboratory; and under the direct supervision of Mr. M. B. Boyd, Chief of the Waterways Division, Hydraulics Laboratory; and Dr. L. L. Daggett, Chief of the Navigation Branch, Waterways Division. The principal investigators in immediate charge of the study were Messrs. C. J. Huval and J. C. Hewlett of the Navigation Branch. They were assisted by Mr. John Cartwright, Estuaries Branch, Waterways and Estuaries Division, Hydraulics Laboratory. Assisting in preparation of the report were Mr. R. A. McCollum, Navigation Branch, and Mrs. M. V. Edris, technical writer, MEVATEC Corporation, Inc., Vicksburg, MS.

Director of WES during preparation of this report was Dr. Robert W. Whalin, and COL Bruce K. Howard, EN, was the Commander of WES.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048	meters
knots (International)	0.5144444	meters per second

1 Introduction

Physical Description

The Southwest Pass Entrance of the Mississippi River is located in southeastern Louisiana in the Gulf of Mexico (Plate 1). Although this channel is one of several distributary channels at the mouth of the Mississippi, it is the only one maintained for deep-draft navigation. The present authorized channel is 600 ft wide and 40 ft deep below Gulf Coast Low Water Datum (GCLW). The channel provides access to shallow-draft vessels entering the Mississippi River inland waterway system while the ports of New Orleans and Baton Rouge are the destinations for deep-draft traffic. The entrance area to the deep-draft channel in the Mississippi River is critical because frequent maintenance dredging is required due to the interaction of coastal tides and fresh water outflow. This zone's primary components are the large fresh water discharge from the Mississippi and the counteracting higher density seawater pushing upstream near the bottom as a salt water wedge. The interaction zone's location changes with flow magnitude and results in a shifting sediment bar within the channel. Also, since the hull of a deep-draft vessel comes in contact with both layers of this stratified flow, the effective current force on transiting ships reflects the changing interaction as well.

Purpose and Scope

The U.S. Army Engineer District, New Orleans, originally proposed deepening the Mississippi River channel to 55 ft; however, due to economic reasons this was reduced to 45 ft. This modification allows ships calling at the Ports of New Orleans and Baton Rouge to load deeper, enhancing the overall efficiency of the shipping channel. The New Orleans district requested the Waterways Experiment Station (WES) to conduct a ship simulator to determine channel width requirements for safe transit of deeper draft vessels. Channel dimension design is critical in the entrance area because any enlargement in cross section is expected to cause increased maintenance dredging. The simulator study encompassed only the entrance area; however, it was expected that the resulting width of the interior channel could be extended to the rest of the Mississippi River channel.

Since the purpose of the channel improvement is deepening to 45 ft, the primary consideration of the simulator study was channel width. To determine widening requirements, four different channel configurations were included in the simulator test program (Plate 2):

a. 600 ft wide and 40 ft deep (authorized condition).

b. 600 ft wide and 45 ft deep (pilots' opinion of what actually exists).

c. 675 ft wide and 45 ft deep.

d. 750 ft wide and 45 ft deep.

The channel widening was constructed and modeled in the simulator data bases on the western side due to the close proximity of dikes and jetties on the eastern side of the channel through the bend (Plate 1).

2 Data Development

To simulate the study area, the following five types of input data were developed:

a. A channel data base containing geometry for the existing channel and the proposed channel modifications. It includes coordinates for the channel cross sections, adjacent submerged bank slope angle, water depth of adjacent areas at the top of the sloped bank, initial vessel conditions, and autopilot definition.

b. A visual scene data base for the generation of a projected computer visual image included coordinates and geometric descriptions of visible physical features in the simulated area, such as aids-to-navigation, land, and jetties.

c. A radar data base with geometric descriptions of land masses and objects adjacent to the navigation channel similar to those on ship-board radar.

d. A ship data file with characteristics and hydrodynamic coefficients for the test vessels.

e. A current data base with the magnitude and direction of the current including the channel depth across each cross section defined in the channel data base.

Channel

The District provided the hydrographic survey charts (dated 21 May 1986) used to develop the channel data base. State plane coordinates from these surveys defined the data. The simulator test channel for the study area has 40 cross sections covering the channel from the sea buoy to the bend at mile 20 and upriver from there approximately four miles. The authorized existing

channel was modeled with a 600-ft width and a constant 40-ft (GCLW) depth; in addition, the existing channel was modeled with a 45-ft (GCLW) depth because the pilots considered this the actual condition, allowing ships with drafts up to 44 ft to enter. A constant 45-ft (GCLW) depth simulated the three proposed deepened channels. The outside (western) corner of the bend for the two widened channels was rounded off in the simulation (Plate 2). This was a test error but did not have significant effect on the results because pilots generally cannot effectively use this type of corner configuration.

The ship simulator model allowed eight equally spaced points to define each cross section. At each of these points, a depth, current magnitude and direction were input. Also, for each cross section, the right and left bank slopes and overbank depths were input to calculate bank effects. The cross-section water depth data was taken from the New Orleans District hydrographic survey. Water depth was used in the main program predominantly for calculating bank suction forces and shallow water effects on vessels.

Visual Scene

The hydrographic survey maps, National Oceanic and Atmospheric Administration (NOAA) charts, photographs, and personal observations made during field inspection were used to create the visual scene data base. These information sources allowed inclusion of the significant physical features in the area and determined what the pilots used for informal ranges and location sightings. The visual scene included aids-to-navigation such as buoys, channel markers, land masses, and jetties. These objects are in a two-dimensional perspective image projected onto a wall screen viewed by the pilot conducting the test. Also, the bow of the ship is visible in the foreground of the visual scene and all objects are seen in their correct relative position. A "viewing angle" is read from the ship's console to create a look-around feature on the simulator. This allows pilots to look at objects outside the straight-ahead view which encompasses approximately forty degrees. This feature simulates the pilot's ability to see any object with a turn of his head. Also the pilot's position on the bridge can be changed from the center of the bridge to any position perpendicular to the ship heading to simulate the pilot walking across the bridge to obtain a better view, e.g. to see along the edge of the ship from the bridge wing. It should be noted that creating a visual scenario for a project is difficult in terms of engineering judgment and optimization of computer time. The goal is to provide all the required data without excessive visual clutter, considering the finite storage memory and computational resources available on the minicomputer.

Radar

The graphic image generator uses the radar data base to create a simulated radar for the test pilots. The radar data base contains the state plane coordinates defining the border between land and water. The file also contained coordinates for major important physical features that might appear on radar such as jetties and aids-to-navigation. In short, this data defined what a pilot actually sees on shipboard radar. The radar image is a continuously updated view of the vessel's position relative to the surrounding area. Three scales were programmed allowing the pilot to choose the range of the display.

Test Ships

The ship data base included the ship characteristics and coefficients used in the hydrodynamic program for calculating forces on the test ships. Two ship models were used during the testing program. For the authorized (existing) 40-ft-depth channel an 87,000-deadweight ton (DWT) tanker 763 ft long, 125 ft wide, with 39-ft draft was used. For the three deepened 45-ft channels (proposed conditions), the tanker's geometric dimensions were increased to simulate a larger vessel, 840 ft long and 138 ft wide. Also, the mass and moment of inertia were modified for the larger ship. The smaller ship represented the typical vessel presently entering the Mississippi River and the larger ship was the design vessel for the deepened project. The water depths and vessel drafts in the testing program were designed to keep the underkeel clearance at 1 ft in the two channel depths to simulate actual pilot practice.

Current

The current data bases for this study were created using data from both physical and numerical models. Normally a two-dimensional TABS-MD finite element, depth averaged model is used to generate the currents for use with ship simulator studies. Such a model was developed to compute the fresh water flow patterns for a high riverflow of 1,300,000 cfs and for a low riverflow of 640,000 cfs at Venice. This provided magnitude and directions of freshwater flows throughout the lower river reaches. In creating this model, water was allowed to “leak” out of the river between the jetties since they are porous and some portion of the flow does escape into the Gulf of Mexico through the jetties, especially when the riverflow is high. This leakage was calibrated based on prototype information and physical model results. An example of the velocities computed by the TABS model for the high and low flows is shown on Plates 3 and 4.

We could not use this information directly because of a saltwater layer that travels upstream along the river bottom from the Gulf of Mexico. It had to be adjusted to account for the upriver flow and the varying thickness of the saltwater wedge upriver. The thickness and the distance of the wedge upriver depends upon the river discharge. Based on measurements from the physical model, the velocity of the flow in the wedge and the thickness of the wedge was determined for the high and low riverflows used for this study. It was found that the upriver velocity in the wedge was about 0.5 fps throughout the wedge.

With this information, the TABS velocities for each cross section were adjusted to account for the decreased freshwater cross section due to the presence of the saltwater wedge thickness. That is, the velocities were increased in inverse proportion to the decreased depth of the freshwater flow from the full depth used to calculate the depth-integrated velocities. With this information, a two layered current database was developed for each flow condition and each channel dimension. The data base contained the freshwater depth, the freshwater velocity, the saltwater thickness and the velocity of the saltwater, 0.5 fps.

When each simulation test run was intitiated, the appropriate current database was used to compute the depth integrated velocity affecting the ship based on its draft. The ship draft was determined from the specified ship definition file and the freshwater velocities and saltwater velocities were integrated over that draft. Therefore, a lighter draft ship would be more affected by the freshwater velocities than a deeper loaded ship which penetrates further into the saltwater layer, i.e., the deeper loaded outbound ship was not pushed downriver as hard as a lighter loaded ship. This integrated database was then used for all of the computations for that particular simulation. An example of the velocities computed for a 44-ft drafted ship with both the high and low river flow conditions is shown in Plate 5.

3 Navigation Study

Validation Tests

Two members of the Louisiana Bar Pilots Association visited the ship simulator prior to the testing and validated the Southwest Pass channel simulation. The validation tests were conducted on the ship simulator with the existing channel condition (600-ft width and 40-ft depth). The pilots tested low and high riverflow, wind and no wind, inbound and outbound runs, and small and large ships. The pilots rated each run on accuracy of currents, wind effect, ship handling, bank forces, visual scene accuracy, etc. The model was adjusted as needed to better correspond with their experience.

Based on the validation pilots' comments, several changes were made to the simulator model. Channel markers "6", "8", "5", and "7", upstream of the pilot way station, were added to the visual and radar data bases since the pilots stated that they were used for alignment. After a few trials it was decided that wind would not be included in the test condition because its effect on loaded tankers is negligible. Bank suction forces along the starboard side (inbound) near the Coast Guard Station were increased by making the overbank depth 10 ft. The river current velocities were increased by a factor of 2.0 which is reasonable because the mathematical model used to calculate the currents used an assumed leakage flow. With these changes in place, the pilots agreed the simulation was realistic. The changes made during validation were used for all testing with the existing channel and the proposed channel enlargements.

Summary of Test Conditions

The Southwest Pass Entrance, Mississippi River scenario as implemented on the Waterways Experiment Station (WES) Ship Simulator included the channel from the sea buoy to the bend at Mile 20 and the channel up the Southwest Pass from Mile 20 to Mile 16. Pilot testing was performed with 3 different proposed channel conditions as well as the existing condition. These conditions are:

a. 600 ft wide, 40 ft deep (existing condition).

b. 600 ft wide, 45 ft deep.

c. 675 ft wide, 45 ft deep.

d. 750 ft wide, 45 ft deep

Runs with the existing channel were made with the smaller (763 ft by 125 ft) tanker. All runs with the 45-ft-deep channel were made with the larger (840 ft by 138 ft) tanker. Runs were made both inbound and outbound with low riverflow (640,000 cfs at Venice) and high riverflow (1,300,000 cfs at Venice).

Test Procedure

Testing was done to determine how much, if any, channel widening was needed for safe transit in the deepened channel by deeper draft vessels. Four professional pilots from the Louisiana Bar Pilots Association conducted the formal pilot testing. Involving local professional pilots incorporated their skill, experience, and familiarity with handling ships in this evaluation. The pilots were briefed on the study and introduced to the equipment upon arriving at the WES simulator; then they conducted several familiarization runs in the simulated channels before testing began. The pilots alternated conning the simulator and completed a questionnaire after each test run, rating the difficulty of the run and the accuracy of the simulation. Most test runs required approximately 15-20 minutes to complete. Each pilot had a combination of 16 test conditions (four channel conditions, two directions, and two flow conditions). They were given the opportunity to repeat a run, if desired. During the test program, 95 pilot runs were conducted (Table 1).

Test Results

During each test run by the pilots, the characteristic control measures of the ship were automatically recorded every ten seconds. These control measures included the position of the ship's center of gravity, speed, rpm of the engine, heading, drift angle, rate-of-turn, rudder angle, and port and starboard channel edge clearances.

The simulator tests were evaluated based on pilot ratings, ship tracks, and statistical analysis of the various ship control measures recorded during testing. The following sections will discuss these three methods of analysis.

During analysis of test results, it was discovered that testing for the proposed channels had been performed with the ships' rudder at a maximum of 48 degrees instead of the correct 35 degrees value. To determine what effect

this error had on results, two engineers from WES performed real-time simulation runs using the outbound, high river discharge condition (worst case for navigation) and the correct value of maximum rudder. Although neither of the two WES engineers are pilots, they each have experience in simulator operation. The analysis of these runs were based solely on track plots and control measure plots because no questionnaires were completed. As an additional check on the results, recorded data from the professional pilot runs were used as autopilot input on the simulator, limiting the rudder command angle to 35 degrees. In this way, the pilot runs were "rerun" to determine the impact of the 48 degree maximum rudder angle. These particular results were analyzed solely on the basis of track plots. The discussion concerning these efforts will be presented below after the section on the original pilot tests.

Pilot's Rating

Two questionnaires documented the pilots' comments about the simulator and the proposed channel improvements and rate the runs. One questionnaire went to the pilots after each run and a final debriefing questionnaire was given after the pilots' completed all testing. For each run, the pilots gave a rating on the difficulty of the run and the turn, amount of attention required, danger of running aground and/or hitting an object, and the realism of the ship, current, and bank forces.

Table 2 shows the mean and the standard deviations of the pilots' ratings for each test condition question. The standard deviation for most questions was very high due to a large variance in how the pilots answered each question. For example, on several questions the rating given by the pilots varied from 1 to 10, even though they were responding to the same question for the exact same condition. Since the pilots' opinions varied widely, analysis of the ratings can only yield relative evaluations of how conditions changed.

Comparing the means of the difficulty of the runs, it can be noted that the ratings differed very little between the tested channel conditions. This can also be noted in the amount of attention and the difficulty of the turn. It appears the pilots believed the tested channel conditions were, for the most part, equally difficult. The pilots gave no indications by their ratings that widening the channel would improve navigation.

Composite Ship Track Plots

Composite ship track plots for pilot testing are shown in Plates 6-37. Pilot tracklines are depicted by overlaid ship images indicating the ship location and orientation at different times during transit; the lines show the defined channel and bankline. The important feature is the relative position of the ship in the defined channel. The other features are provided for reference.

Outbound runs

High river discharge (Plates 6-9). All pilots followed approximately the same path near the center of the channel prior to the small right turn upriver of the USCG station. However, after this turn some spreading of the composite track plots can be seen for all channel sizes. After the main entrance left turn, a wide variation of ship paths occurs except in the 600-ft by 40-ft channel which is the authorized condition. This indicated the pilots are possibly unfamiliar with the handling of the larger tanker tested in the deepened channels. According to the pilots, once past the shoal in the immediate vicinity of the entrance turn, they considered themselves beyond the entrance and can safely leave the confines of the authorized channel.

Low river discharge (Plates 10-13). These track plots are similar to the high flow runs in Plates 6-9 except three cases with 600-ft and 675-ft wide channels. In these channels, some ship tracks go beyond the west side of the channel opposite the USCG station. Although no pilot drifted beyond the channel edge in the 750-ft channel (Plate 13) area, the composite track was farther to the west than in high riverflow (Plate 9). This tendency to steer toward the outside of turns agrees with observed pilot strategy in other simulations conducted at WES. The pilots tried to follow this same strategy for both the high and low riverflows, in this simulation. However, the track plots showed the vessels passed closer to the inside of the bend and nearer to the USCG station at high riverflows than during low riverflow. These results suggest that high flows push ships closer to the middle of the channel. This comparison of low flow and high flow pilot runs suggests that widening the western side of the channel opposite of the USCG Station would improve navigation conditions in the bend. During low flows this would accommodate the pilots' steering strategy towards the outside of the bend. In high flows it would allow pilots to move to the western side of the channel earlier; minimizing the tendency for the ship to drift toward the inside of the bend.

Inbound runs

High river discharge (Plates 14-17). Generally the pilots had little trouble handling the ships in the four test channels. The only excursion beyond the channel limits was on the western side of the 600-ft by 45-ft channel near the upstream end of the run.

Low river discharge (Plates 18-21). The pilots had almost no difficulty in navigating the four test channels. The seeming ease of inbound runs on the simulator agreed with pilot opinion and was due to good control against oncoming currents. With following currents, during outbound runs, the pilots had less control.

Plates 22-37 show the plotted test results according to test channel size and individual pilots. In the authorized existing channel (Plates 22-25), several pilots came close to but did not drift beyond the channel edge. However,

pilot C drifted beyond the channel edge along the western side opposite the USCG station. In Plates 26-32 (all proposed channels) the ship track plots show higher variability and the occurrence of several channel edge excursions. These results indicated the increased difficulty of handling a larger ship in the area. Although pilot A followed a fairly consistent pattern in the area adjacent to the USCG station in the three proposed channels (Plates 26, 30, and 34), the tracks of the other three pilots all show greater variability. Plates 34-37 show no excursions beyond the channel limits in the 750-ft width in the area adjacent to the USCG station.

Statistical Analysis

During each run, the control measures of the ship were recorded every 5 seconds. These control measures included coordinate position, speed, propeller revolutions per minute (RPM), rudder angle, rate of rotation, heading, drift angle, and port and starboard channel edge clearances. For the following statistical evaluation of the recorded simulations, each control parameter listed above was plotted as a running mean. These means are obtained by averaging parameter values from all pilot runs over each 500-ft-long channel segment. This obtains a smoothed record of an "average" pilot performance. Additionally, the running average variability, represented by the parameter standard deviation, was obtained in the same manner and plotted for selected parameters. The test conditions will be grouped according to travel direction and river discharge; then, the results of the four channel conditions will be compared based on this grouping.

It should be noted that the speed and RPM plots indicated the pilots used maximum RPM for all runs. Deflection of the rudder in the turn caused the change in speed seen on the plates. This was a common practice for all the pilots during the testing. The control measure plots of speed and RPM will be presented for each test condition, but will not be discussed further, since the speed varied little and the RPM's did not vary. Also, a word of caution is needed in interpreting these control measure plots. For inbound runs the ship proceeded through the channel from left to right on the plot. However, for outbound runs the distance along track was plotted the same but the ship's travel direction is from right to left on the plots. The maneuvering factors are shown on the same plots as the rudder angle and were obtained by multiplying the rudder angle at each time-step with the RPM value for the same time. This was a purely relative measure of pilot maneuvering directly correlated to the applied rudder moment. Predominantly, in the Southwest Pass simulation, as stated above, the pilots did not vary the ship RPM; therefore, the plots of the maneuvering factor generally follows the rudder plots closely.

Inbound runs

Low river discharge (Plates 38-41). The clearance plots (Plate 38) indicated little problem with the tested channels. The 600-ft by 45-ft channel runs averaged a minimum clearance just under 100 ft on the starboard near the USCG station after completing the turn. Since the 600-ft by 40-ft channel had no clearance problems, the low clearance for the deeper channel may be due to the larger ship used for the deeper channel and the lack of pilot familiarity with this size vessel. Rudder plots (Plate 39) indicated fairly similar patterns for each channel dimension. However, the plots show that pilots in the 600-ft by 45-ft channel did not use as much port rudder to maneuver the ship toward the center of the channel as they did in the other channels. The rate-of-turn (Plate 40) also indicated that pilots in the 600-ft by 45-ft channel started their turn about the same as the other channels, but held a high rate-of-turn longer than the other channels. This lack of familiarity with the larger vessel in the narrowest channel, would contribute to the clearance difficulty upon completing the turn.

High river discharge (Plates 42-45). Starboard clearances for all runs were in excess of 100 ft at all times (Plate 42). Port clearance indicated a minimum of about 90 ft approximately half-way between the USCG Station and the abandoned pilot house for the 600-ft by 40-ft channel and about 105 ft at the abandoned pilot house for the 600-ft by 45-ft channel. Rudder angles (Plate 43) for the 600-ft by 40-ft channel were consistently less than the other channels throughout the run. The pilots used the largest amount of port rudder in the area where they came closest to the port edge of the channel (Plate 14), possibly over-compensating for the current set. The pilots in the other test channels used the same pattern, except with larger values of rudder. The 750-ft by 45-ft channel required the largest rudder value to make the turn and the highest rate-of-turn was achieved (Plate 44). For the 600-ft by 45-ft channel more rudder was required than in the 600-ft by 40-ft channel, but less than in either of the wider channels.

Outbound runs

Low river discharge (Plates 46-49). Clearance values (Plate 46) on the starboard side at the USCG Station were very low for the 600-ft channels, approximately 100 ft for the 675 ft, and in excess of 200 ft for the 750 ft. Port clearance at Buoy 3 was approximately 100 ft for all the 45-ft deep channels. The port clearance at this point for the 600-ft by 40-ft channel was approximately -10 ft, indicating a strong tendency for drifting beyond the channel edge. All the rudder plots (Plate 47) show a steady increase of port rudder to compensate for the current and make the turn, then a decrease as the turn is completed, and finally a small value applied to correct for the current set. Rudder plots indicated no starboard rudder use after completion of the turn and was probably due to the pilots' anticipation of the set to the starboard side. The pilots using the 600-ft by 40-ft channel apparently misjudged the current set or the point to begin the turn. The rate-of-turn plots (Plate 48) for the

600-ft by 40-ft channel showed the turn began earlier than other channels, held for a long period and dropped off quickly, even going into a slight starboard turn to pull away from the port side. The pilots in the 750-ft channel started the turn later with a higher rate-of-turn than in the 675-ft channel; however, the clearance values for either channel are adequate.

High river discharge (Plates 50-53). Clearance plots (Plate 50) indicated no major difficulties except for the 600-ft by 45-ft channel on the starboard side near buoy 1 with a less than 100-ft clearance. When the clearance plots are compared to the track plots (Plates 6-9), it is obvious that gaining control after completion of the turn was difficult for all channel conditions. Clearance plots are the average of the minimum clearance values for each pilot run for each 500-ft distance along the channel. The majority of pilot runs stayed in channel boundaries and was reflected in the clearance plots. The runs near the channel boundaries on either the port or starboard side (trackplots, Plates 6-9) tended to average each other out, still showing the ship to be well within the channel on the clearance plots. The 750-ft channel appears more difficult in the turn than the narrower channels. Rudder activity (Plate 51) for all runs was very similar, except in the 600-ft by 40-ft channel where pilots reduced the port rudder sooner than in the other channels. The rate-of-turn (Plate 52) indicated pilots took advantage of the 750-ft channel, dropped the rate-of-turn much sooner than the other channels and allowed the ship to drift to starboard with the current. The pilots appeared more deliberate in making the turn with the smaller channels, holding the rate-of-turn longer and was probably due to the reduced margin for error. This was reflected in the track plots (Plates 6-9), since the 600-ft-width and the 675-ft-width channels' plots have a much tighter pattern after completion of the turn than did the 750-ft channel.

WES pilots

Two engineers from the WES Simulation Group conducted real-time operation of the simulator with the same channel conditions and ship control measures as the professional pilots, except limiting the rudder to the correct maximum of 35 degrees. To expedite the testing, the WES pilots operated only outbound runs with high river discharge, which was considered the worst case condition for navigation. The ship track plots and navigation control measure plots will be evaluated by themselves and compared to the professional pilots' results.

Track plots (Plates 54-57). The track plots for the 600-ft by 40-ft channel stayed in the channel (Plate 54). Passing close to the starboard channel edge in the turn approach and then cutting to the inside of the bend was the general pattern. The 600-ft by 45-ft channel results were very similar, except the tracks tended to be more uniform (Plate 55). Some difficulties controlling the starboard set after completion of the turn was evident. The 675-ft by 45-ft channel results (Plate 56) showed a similar pattern as the two smaller channels with a tendency to cut across the inside of the turn. The 750-ft by 45-ft channel trackplots (Plate 57) showed a larger variance in the turn approach

compared to the other channels, but the tracks tended to be farther away from the port side during the turn. Difficulty in overcoming the starboard drift was evident.

Navigation control measures (Plates 58-61). Plots of clearances (Plate 58) indicated little difficulty with any channel width. The port clearance for the 675-ft channel was about 90 ft at the center of the turn. The rudder patterns (Plate 59) were very similar for all the runs, except the pilots in the 675-ft channel started turning slightly earlier than the other channels. This was reflected in the rate-of-turn (Plate 60). As with the professional pilots, the WES pilots used full engine power for almost all runs; therefore, the speed and engine rpm plots (Plate 61) for each test channel were almost identical.

Comparison of WES pilots to professional pilots. The track plots of the WES pilots (Plates 54-57) indicated no major differences from the professional pilots (Plates 6-9). The control measure plots were very similar except the rudder percentages and the rate-of-turns. The rudder plots are in percent of the maximum rudder available; therefore, the percentage used by the WES pilots will be higher due to the limited 35 degrees maximum rudder instead of 48 degrees for professional pilots. The rate-of-turn for all tested channels was somewhat higher than the professional pilots and could be due to the difference in strategies to make the turn. The rudder plots showed the professional pilots tended to have a shorter duration of large rudder values as compared to the WES pilots. This would give them a smaller rate-of-turn peak value, but a comparison of the rate-of-turn plots indicated professional pilots held a longer sustained rate-of-turn. Professional pilots' lower peak rate-of-turn and longer duration of turn yielded similar results as the WES pilots' larger rate-of-turn peak value and shorter duration of turn strategy.

The comparisons of the professional pilots runs with the WES pilots runs shows no major change caused by the difference in the maximum available rudder angle. Test results of the professional pilots runs were deemed to be valid. Conclusions from the testing results will be made with the maximum rudder value in consideration.

Fast-Time Runs

To further assure testing results were not biased due to the maximum available rudder angle error, the real-time runs by professional pilots for the outbound case with low and high river discharge were rerun in simulator fast-time mode. The pilots'rudder and engine rpm commands were used as autopilot input, yielding a fast-time run with exactly identical commands. However, the maximum rudder for these runs was limited to the correct 35 degrees. The track plots of these two runs (real-time and fast-time) can be compared for the differences caused by the maximum available rudder limit.

Low river discharge

The 600-ft by 40-ft channel trackplots (Plate 62) indicated a pilot tendency to approach the starboard edge of the channel before the turn. After beginning the turn the pilots cut to the inside near the USCG Station. The 600-ft by 45-ft channel trackplots (Plate 63) showed a similar pattern, except the tracks were somewhat closer to the starboard before beginning the turn. When the tracks take a wider turn, they appeared in better position on turn completion. The 675-ft by 45-ft channel trackplots (Plate 64) indicated a similar pattern to the 600-ft channels, except the tracks tended to be closer to the center of the channel before beginning the turn. With this channel, the tracks making the wider turns tended to go near the starboard edge of the channel after completing the turn. Tracks with tighter turns appeared to have better port clearances than the 600 -ft channels. The 750-ft by 45-ft channel trackplots (Plate 65) held very close to the channel center through the runs.

High river discharge

Plate 66 (600-ft by 40-ft channel) showed the plots running almost along the center line of the channel up to the turn, then cutting to the inside of the turn. All plots tended to be close to the starboard side as they completed the turn. Plate 67 (600-ft by 45-ft channel) showed a similar pattern up to the beginning of the turn. The pilot track lines generally indicated a tendency toward a wider turn, coming much closer to the starboard edge of the channel on turn completion. Plate 68 (675-ft by 45-ft channel) showed tracklines following a similar pattern in the turn approach as the 600-ft channels, but as in the 600-ft by 45 -ft channel, the turns were wider and came closer to the starboard side with several channel edge excursions. Plate 69 (750-ft by 45-ft channel) showed a similar pattern to the 675-ft by 45-ft channel. The turns appeared better than the 675-ft channel, but several groundings on the starboard side are noted.

Comparison

The track plot patterns from real-time runs and fast-time runs were very similar. The fast-time runs with the 35 degree maximum rudder tended to show the turns slightly wider than the real-time runs with the 48 degree maximum rudder. The maximum rudder plots used by the WES pilots for real-time (Plate 59) showed that even with a maximum 35 degree rudder, only about 75-80 percent was used to complete the turn on the outbound runs with high river discharge. The fast-time runs used recorded pilot commands for the rudder for the corresponding test condition except the limitation to a maximum 35 degrees rudder. The fast-time runs were not definitive on how the pilots would have performed with the correct rudder value. However, they supported the conclusion that the error in maximum rudder value for real-time testing with professional pilots did not affect the outcome of testing significantly.

4 Conclusions and Recommendations

Conclusions

The high river track plots of the outbound transits (Plates 7-9), showed a few excursions beyond the channel limits on the western side, downstream from the turn. Plate 35 showed these excursions were predominantly made by pilot B while the other three pilots remained within channel limits. According to comments by pilot B this strategy is his normal practice. Therefore, it appears the excursions are the result of an individual preference and cannot be interpreted as evidence supporting channel widening in this area.

The test results of the Southwest Pass Simulation Study indicated the following conclusions:

a. The larger design vessel will be able to safely navigate through the Mississippi River entrance.

b. Safe navigation with the larger tanker is not dependent on the tested channel widths; however, widening the channel at the turn will enhance safety.

c. Pilots prefer to use the outside of the bend opposite the USCG station.

d. The inadvertent error of testing with a 48 degrees maximum rudder did not significantly effect testing results.

Recommendations

The simulation tests indicated that safe transit through the Southwest Pass Entrance Channel and turn were not directly dependent on channel width, except at the turn. When available, the pilots tended to use the extra channel width, in the turn, allowing them to make a wider turn and stay off the channel

edge on the inside of the turn. Based on the outbound track plots (Plates 6-13), the 750-ft-width is probably not required for safe passage; therefore, a 700-ft-width channel at the bendway is recommended as indicated in Plate 70. Retaining the existing 600-ft channel width for the remainder of the channel is also recommended.

It should be noted that the recommended widened section may result in slightly increased maintenance dredging requirements along the widened reach, which includes about 3,000 ft. This will likely be noticed in the western channel edge and proceed toward the channel centerline. The numerical sediment transport model tests (2-D) conducted previously for the 55-ft-deep channel with varying channel widths indicated the depth shoaling rate in this area was relatively insensitive to channel width over a range of widths from 600 ft to 750 ft. These results suggested the shoaling volume for the recommended channel could increase by about 17 percent (700/600 = 1.17) along the widened channel reach compared to the 600-ft-wide channel.

Table 1
Summary of Piloted Test Runs - Southwest Pass, Louisiana

No.	Pilot	Start Time	End Time	Channel (ft)	Transit Dir.	Riverflow
May 13, 1987						
1	A	1404	1415	600 X 40	Outbound	Low
2	B	1419	1432	600 X 40	Inbound	High
3	A	1436	1503	600 X 40	Inbound	High
4	B	1512	1529	600 X 40	Inbound	High
5	A	1534	1550	600 X 40	Inbound	High
6	B	1555	1607	600 X 40	Outbound	High
7	A	1610	1621	600 X 40	Outbound	High
8	B	1623	1639	600 X 40	Inbound	Low
May 14, 1987						
9	A	0823	0840	600 X 45	Inbound	High
10	B	0842	0903	600 X 45	Inbound	High
11	A	0907	0926	675 X 45	Outbound	High
12	B	0928	0940	675 X 45	Outbound	High
13	A	0943	0955	600 X 45	Outbound	High
14	B	0958	1011	600 X 45	Outbound	High
15	A	1016	1027	750 X 45	Outbound	High
16	B	1028	1042	750 X 45	Outbound	High
17	A	1046	1103	675 X 45	Inbound	High
18	B	1104	1124	675 X 45	Inbound	High
19	A	1129	1141	750 X 45	Outbound	Low
20	B	1144	1157	750 X 45	Outbound	Low
21	A	1250	1302	600 X 45	Outbound	High
22	B	1306	1317	600 X 45	Outbound	High
23	A	1323	1335	600 X 40	Outbound	Low
24	B	1337	1350	600 X 40	Outbound	Low
25	A	1355	1409	750 X 45	Outbound	High
26	B	1410	1423	750 X 45	Outbound	High
27	A	1427	1438	675 X 45	Outbound	Low
28	B	1441	1458	675 X 45	Outbound	Low
29	A	1501	1513	675 X 45	Outbound	High
30	B	1514	1528	675 X 45	Outbound	High

(Sheet 1 of 4)

Table 1 (Continued)						
No.	Pilot	Start Time	End Time	Channel (ft)	Transit Dir.	Riverflow
31	A	1530	1543	750 X 45	Outbound	Low
32	B	1545	1559	750 X 45	Outbound	Low
33	A	1602	1615	600 X 45	Outbound	Low
34	B	1616	1630	600 X 45	Outbound	Low
35	A	0806	0817	750 X 45	Outbound	High
36	B	0819	0830	750 X 45	Outbound	High
37	A	0831	0844	750 X 45	Outbound	Low
39	A	0901	0913	600 X 45	Outbound	Low
40	B	0914	0927	600 X 45	Outbound	Low
41	A	0930	0942	600 X 40	Outbound	Low
42	B	0944	0959	600 X 40	Outbound	Low
43	A	1001	1013	675 X 45	Outbound	Low
44	B	1014	1027	675 X 45	Outbound	Low
45	A	1032	1043	600 X 40	Outbound	High
46	B	1045	1057	600 X 40	Outbound	High
May 27, 1987						
47	C	1417	1427	600 X 40	Outbound	Low
48	D	1430	1443	600 X 40	Outbound	Low
49	C	1447	1459	600 X 45	Outbound	High
50	D	1503	1513	600 X 45	Outbound	High
51	C	1516	1528	675 X 45	Outbound	Low
52	D	1533	1544	675 X 45	Outbound	Low
53	C	1547	1559	750 X 45	Outbound	High
54	D	1604	1615	750 X 45	Outbound	High
55	C	1620	1635	600 X 40	Inbound	Low
56	D	1637	1654	600 X 40	Inbound	Low
May 28, 1987						
57	C	0854	0906	750 X 45	Outbound	Low
58	D	0909	0920	750 X 45	Outbound	Low
59	C	0923	0940	750 X 45	Inbound	High
60	D	0942	1000	750 X 45	Inbound	High
61	C	1007	1018	675 X 45	Outbound	High

(Sheet 2 of 4)

Table 1 (Continued)						
No.	Pilot	Start Time	End Time	Channel (ft)	Transit Dir.	Riverflow
62	D	1020	1031	675 X 45	Outbound	High
63	C	1035	1047	600 X 45	Outbound	Low
64	D	1050	1101	600 X 45	Outbound	Low
65	C	1105	1115	600 X 40	Outbound	High
66	D	1118	1129	600 X 40	Outbound	High
67	C	1133	1148	600 X 45	Inbound	High
68	D	1151	1218	600 X 45	Inbound	High
69	C	1223	1234	675 X 45	Outbound	Low
70	D	1237	1249	675 X 45	Inbound	Low
71	C	1252	1302	750 X 45	Inbound	High
72	D	1305	1320	750 X 45	Inbound	High
73	C	1416	1427	600 X 45	Inbound	Low
74	D	1429	1441	600 X 45	Outbound	Low
75	C	1444	1459	750 X 45	Inbound	Low
76	D	1501	1517	750 X 45	Inbound	Low
77	C	1520	1531	600 X 40	Outbound	Low
78	D	1534	1545	600 X 40	Outbound	Low
79	C	1555	1608	750 X 45	Outbound	Low
80	D	1611	1622	750 X 45	Outbound	Low
81	C	1626	1636	600 X 40	Outbound	High
82	D	1638	1649	600 X 40	Outbound	High
83	C	1652	1708	675 X 45	Inbound	High
84	D	1710	1728	675 X 45	Inbound	High
85	C	1732	1748	600 X 40	Inbound	High
86	D	1750	1808	600 X 40	Inbound	High
May 29, 1987						
87	C	0902	0912	600 X 45	Outbound	High
88	D	0915	0926	600 X 45	Outbound	High
89	C	0928	0938	750 X 45	Outbound	High
90	D	0940	0950	750 X 45	Outbound	High
91	C	0954	1010	600 X 45	Inbound	Low
92	D	1012	1027	600 X 45	Inbound	Low

(Sheet 3 of 4)

Table 1 (Concluded)

No.	Pilot	Start Time	End Time	Channel (ft)	Transit Dir.	Riverflow
93	C	1031	1046	675 X 45	Inbound	Low
94	D	1049	1104	675 X 45	Inbound	Low
95	C	1136	1154	600 X 45	Inbound	High

Note 1: In the 600 X 40 ft channel the test vessel was a tanker 763 X 125 X 39 ft. In the deepened chanels the test vessel was a tanker 840 X 138 X 44 ft.

Note 2: The low riverflow corresponds to 640,000 cfs at Venice and the high riverflow corresponds to 1,300,000 cfs.

Table 2
Means and Standard Deviations of Pilot Ratings

Run Condition		Difficulty of Run		Amount of Attention		Ship		Realism of Current		Bank Forces	
Direction	Current	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
600 X 40 (Existing), Small Ship											
Inbound	Low	3.67	1.08	6.67	2.48	5.67	1.67	5.33	2.27	6.33	2.48
Inbound	High	5.75	.87	8.25	1.36	5.50	.85	3.25	.73	3.50	1.80
Outbound	Low	4.25	1.28	5.75	2.18	6.75	1.16	4.50	2.13	5.25	1.96
Outbound	High	4.00	1.25	5.50	2.13	6.75	1.16	4.75	2.07	6.25	1.91
600 X 45, Large Ship											
Inbound	Low	4.50	*	8.50	*	4.50	*	1.50	*	1.50	*
Inbound	High	3.50	.58	6.00	1.83	6.25	1.27	5.75	1.59	4.75	2.07
Outbound	Low	4.25	.68	5.75	2.18	6.50	1.27	4.50	2.13	4.50	2.13
Outbound	High	4.25	.99	6.00	1.94	6.50	1.27	4.75	2.07	5.25	2.28
675 X 45, Large Ship											
Inbound	Low	5.00	*	8.50	*	4.50	*	3.00	*	4.50	*
Inbound	High	4.00	1.05	6.25	2.02	6.00	1.49	5.00	2.05	5.00	2.45
Outbound	Low	4.00	1.25	6.00	2.26	5.75	1.60	4.00	2.36	5.50	2.43

(Sheet 1 of 3)

Table 2 (Continued)

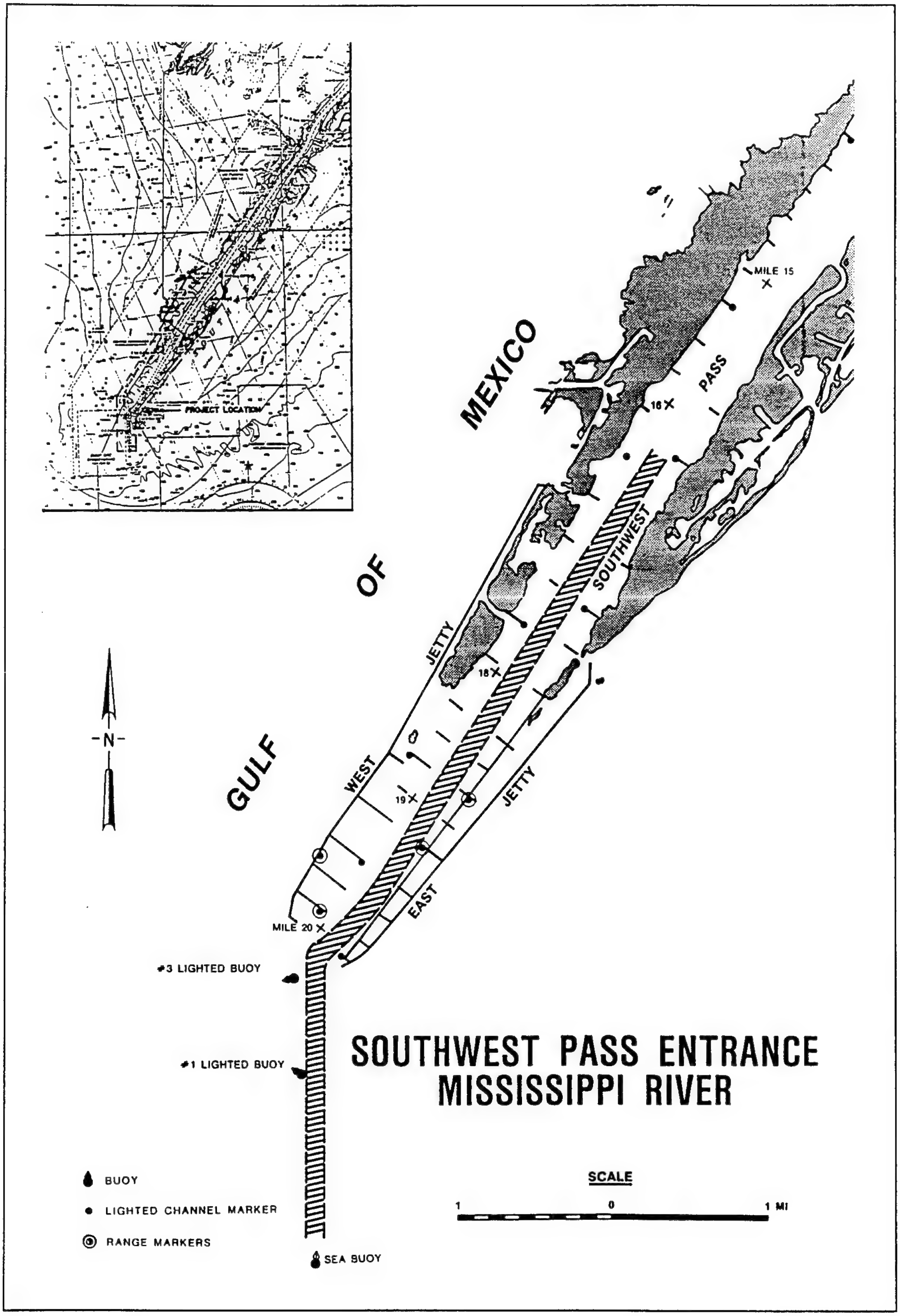
Run Condition		Difficulty of Run		Amount of Attention		Ship		Realism of Current		Bank Forces	
Direction	Current	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Outbound	High	3.75	,87	5.75	1.91	7.00	1.05	4.75	2.07	6.00	2.05
750 X 45, Large Ship											
Inbound	Low	5.00	*	9.00	*	4.50	*	3.00	*	3.00	*
Inbound	High	5.00	*	8.50	*	3.50	*	3.00	*	2.00	*
Outbound	Low	4.25	.43	6.25	2.02	6.75	1.16	4.75	2.02	6.00	2.11
Outbound	High	4.00	.82	6.00	1.94	6.50	1.27	4.50	2.13	5.75	2.23
600 X 40 (Existing), Small Ship											
		Danger of Grounding		Danger of Hitting Object		Difficulty of turn					
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation				
Inbound	Low	1.67	.41	1.67	.41	3.00	1.22				
Inbound	High	5.00	2.36	3.25	2.23	3.25	1.52				
Outbound	Low	2.00	.67	2.00	.67	4.50	1.37				
Outbound	High	1.25	.29	1.25	.29	4.25	1.28				

(Sheet 2 of 3)

Table 2 (Concluded)

Run Condition		Danger of Grounding		Danger of Hitting Object		Difficulty of Turn					
Direction	Current	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation				
600 X 45, Large Ship											
Inbound	Low	6.50	*	5.00	*	6.00	*				
Inbound	High	2.50	1.11	1.75	.55	4.50	1.37				
Outbound	Low	1.50	.58	1.25	.29	4.25	1.28				
Outbound	High	1.75	.55	1.75	.55	4.75	1.09				
675 X 45, Large Ship											
Inbound	Low	2.00	*	2.00	*	6.00	*				
Inbound	High	2.75	.73	2.00	.67	5.00	.82				
Outbound	Low	2.25	1.44	1.25	.29	4.50	1.45				
Outbound	High	1.75	.55	1.75	.55	4.75	1.19				
750 X 45, Large Ship											
Inbound	Low	2.00	*	2.00	*	6.00	*				
Inbound	High	2.50	*	2.50	*	5.50	*				
Outbound	Low	1.50	.33	1.50	.33	4.75	1.19				
Outbound	High	1.75	.55	1.75	.55	4.50	1.00				

* Only two pilot ratings, no standard deviation computed.



SOUTHWEST PASS ENTRANCE
MISSISSIPPI RIVER
GULF OF MEXICO
PROJECT LOCATION
MILE 15
16
PASS
SOUTHWEST
JETTY
18
WEST
19
JETTY
EAST
MILE 20
#3 LIGHTED BUOY
#1 LIGHTED BUOY
N
BUOY
LIGHTED CHANNEL MARKER
RANGE MARKERS
SEA BUOY
SCALE
1
0
1 MI

Plate 1

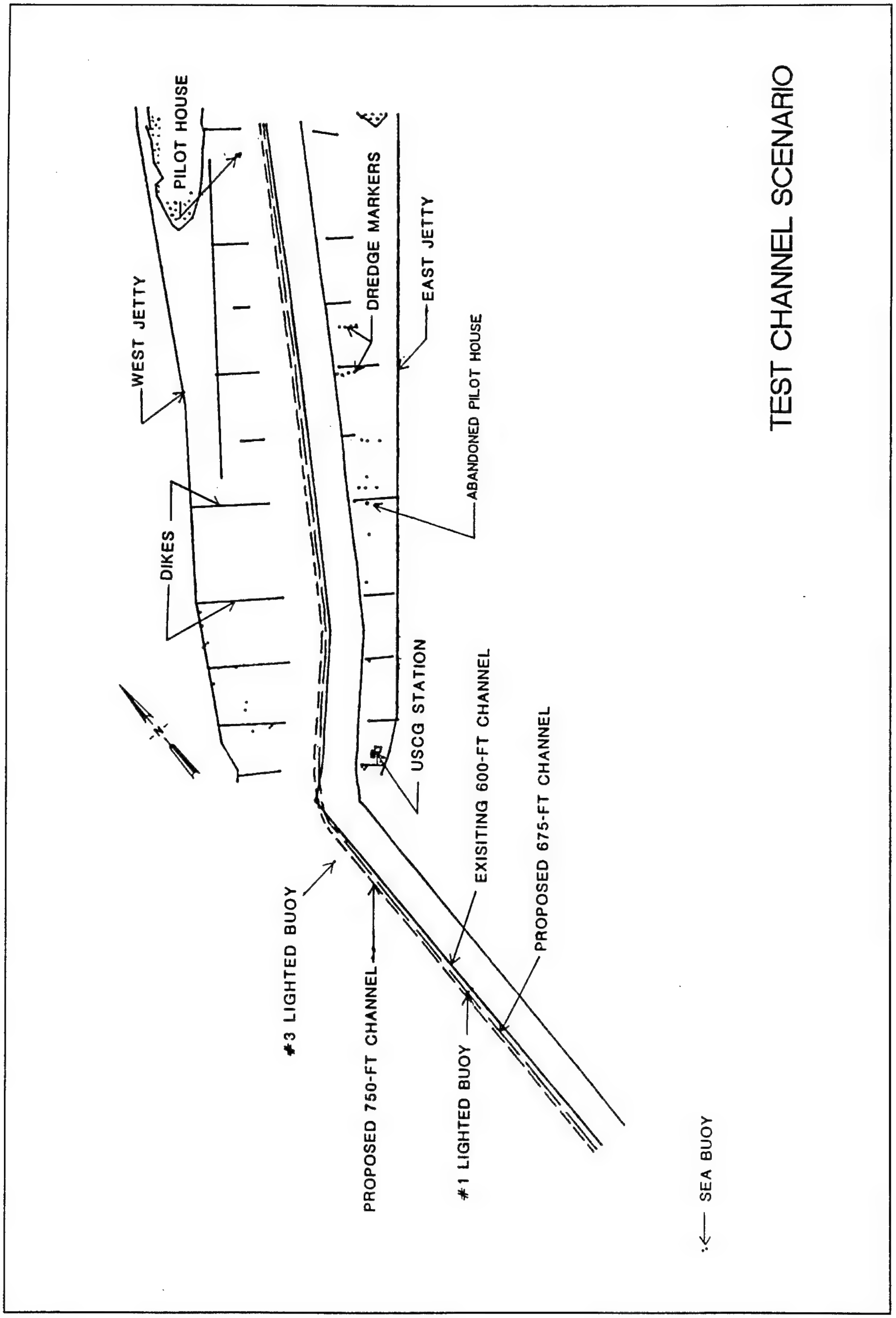

TEST CHANNEL SCENARIO
PILOT HOUSE
WEST JETTY
DREDGE MARKERS
EAST JETTY
DIKES
ABANDONED PILOT HOUSE
N
USCG STATION
EXISITING 600-FT CHANNEL
PROPOSED 675-FT CHANNEL
#3 LIGHTED BUOY
PROPOSED 750-FT CHANNEL
#1 LIGHTED BUOY
SEA BUOY

Plate 2

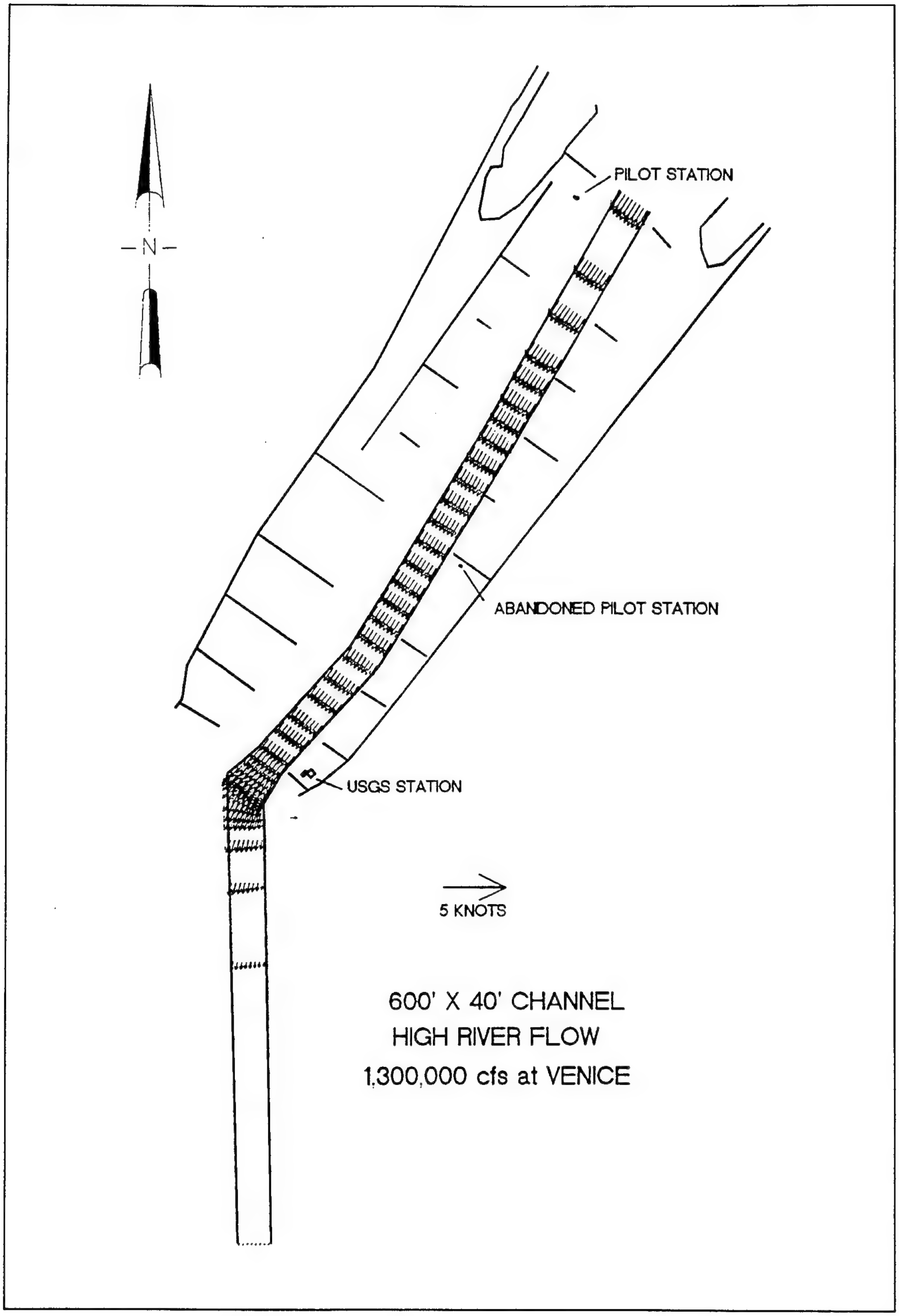
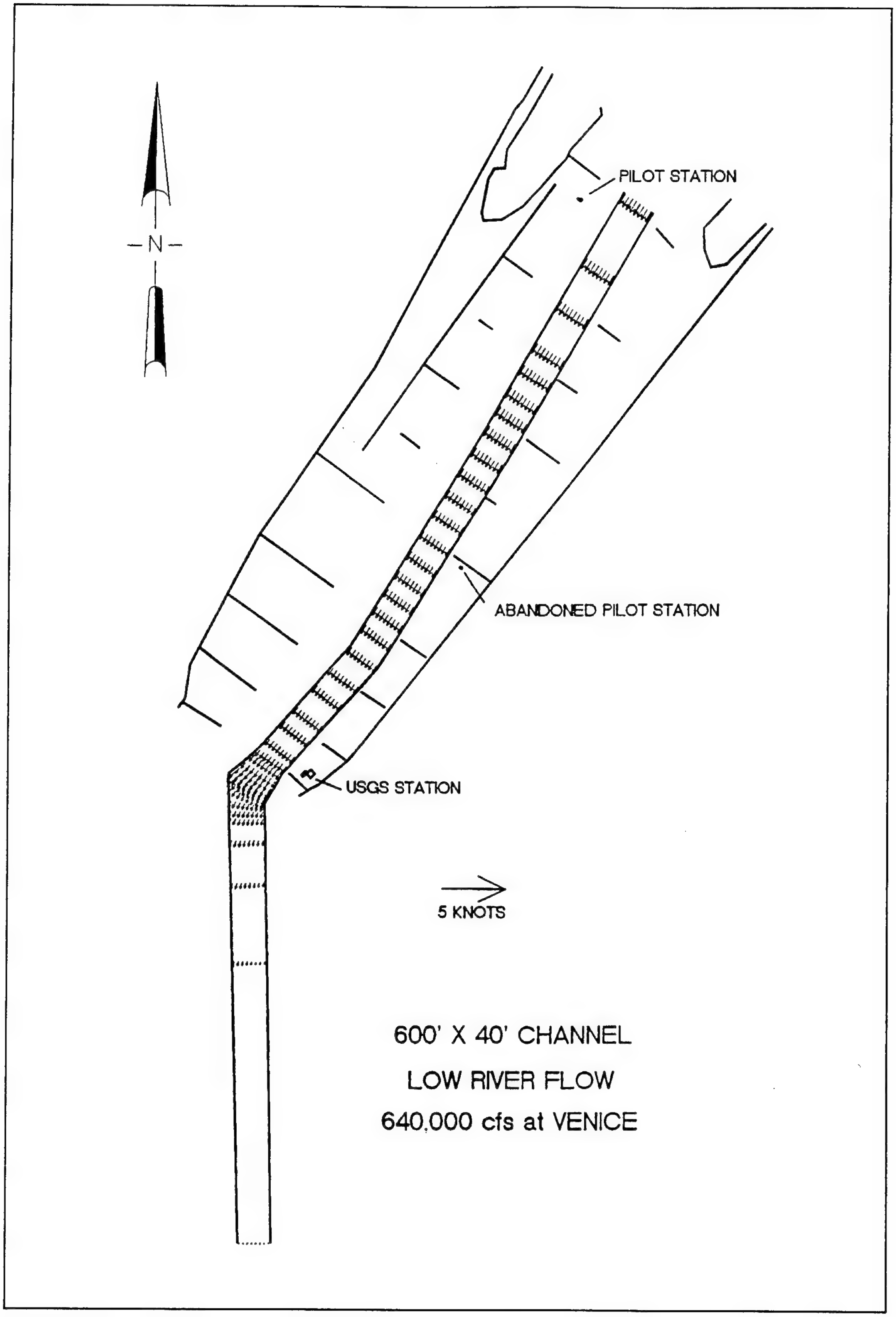
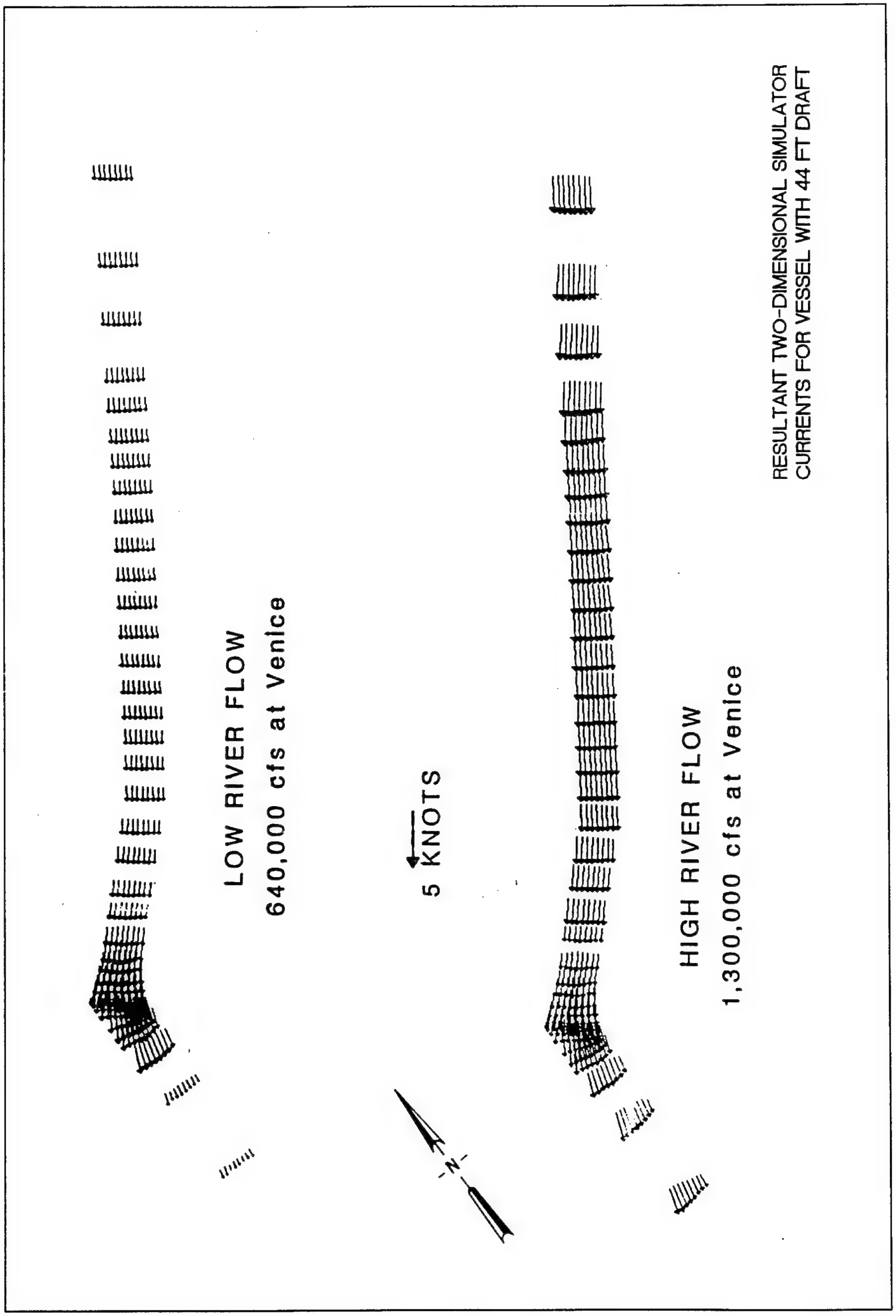

N
PILOT STATION
ABANDONED PILOT STATION
USGS STATION
5 KNOTS
600' X 40' CHANNEL
HIGH RIVER FLOW
1,300,000 cfs at VENICE

Plate 3



N
PILOT STATION
ABANDONED PILOT STATION
USGS STATION
5 KNOTS
600' X 40' CHANNEL
LOW RIVER FLOW
640,000 cfs at VENICE

Plate 4



RESULTANT TWO-DIMENSIONAL SIMULATOR
CURRENTS FOR VESSEL WITH 44 FT DRAFT
LOW RIVER FLOW
640,000 cfs at Venice
5 KNOTS
HIGH RIVER FLOW
1,300,000 cfs at Venice
N

Plate 5

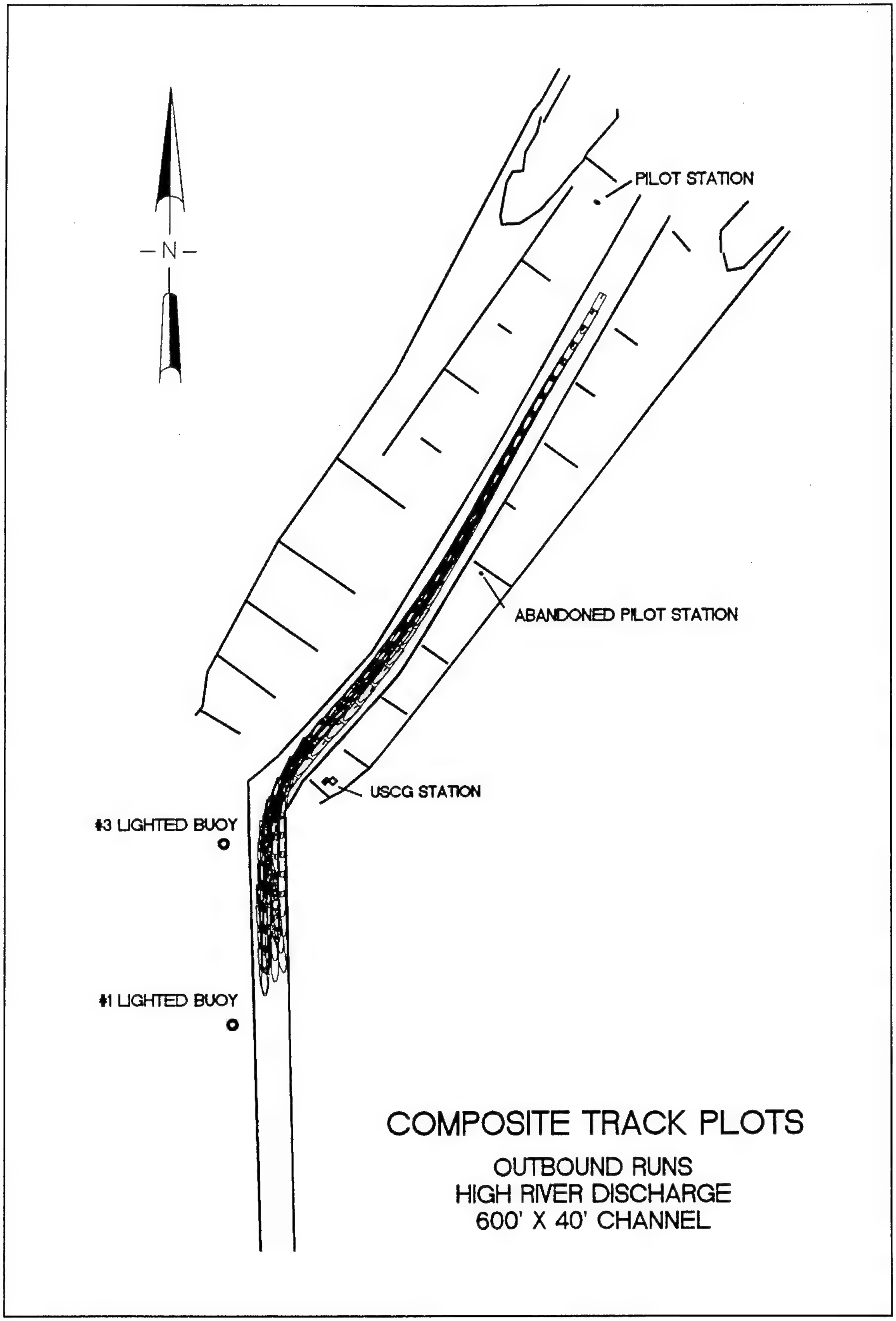
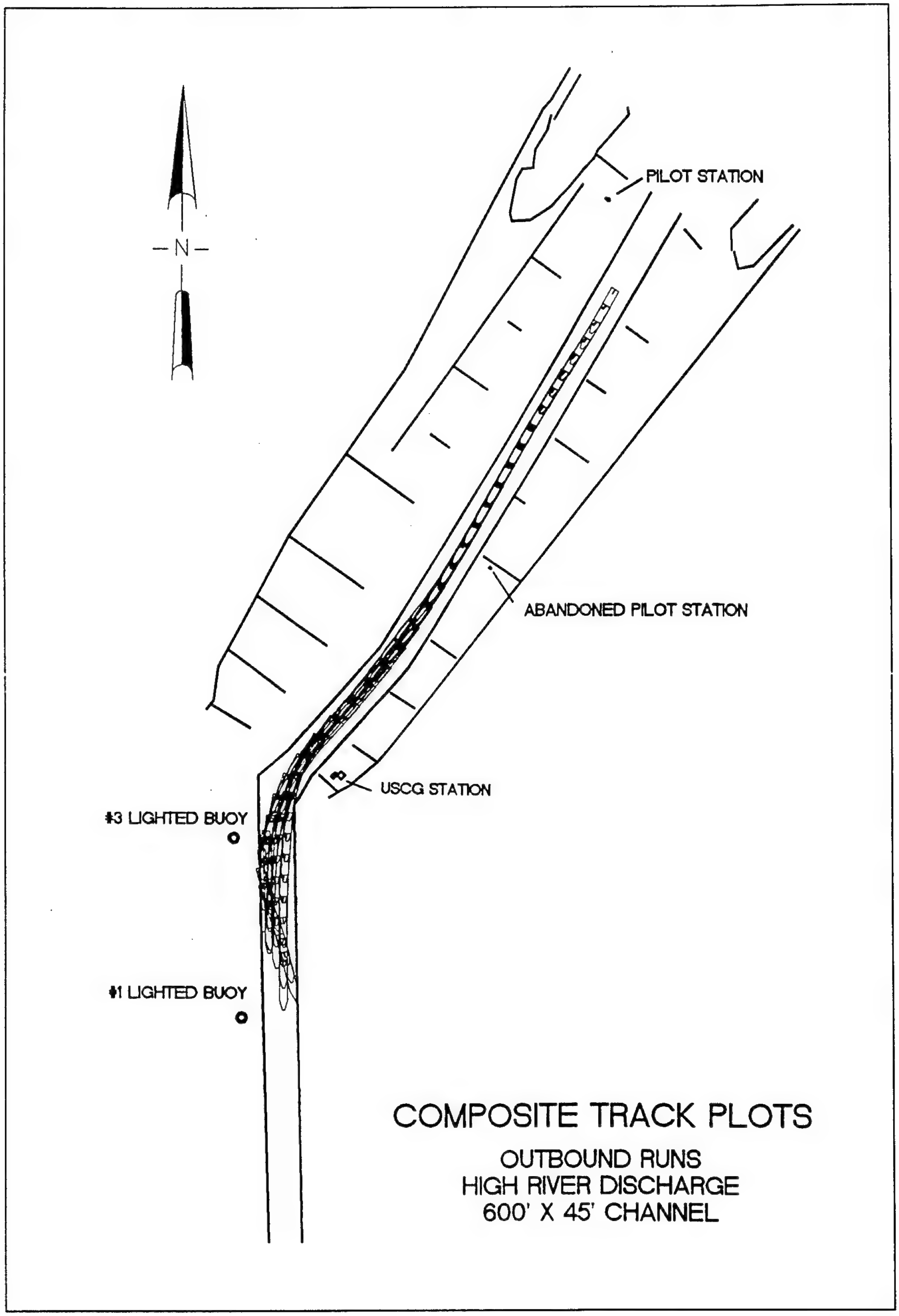
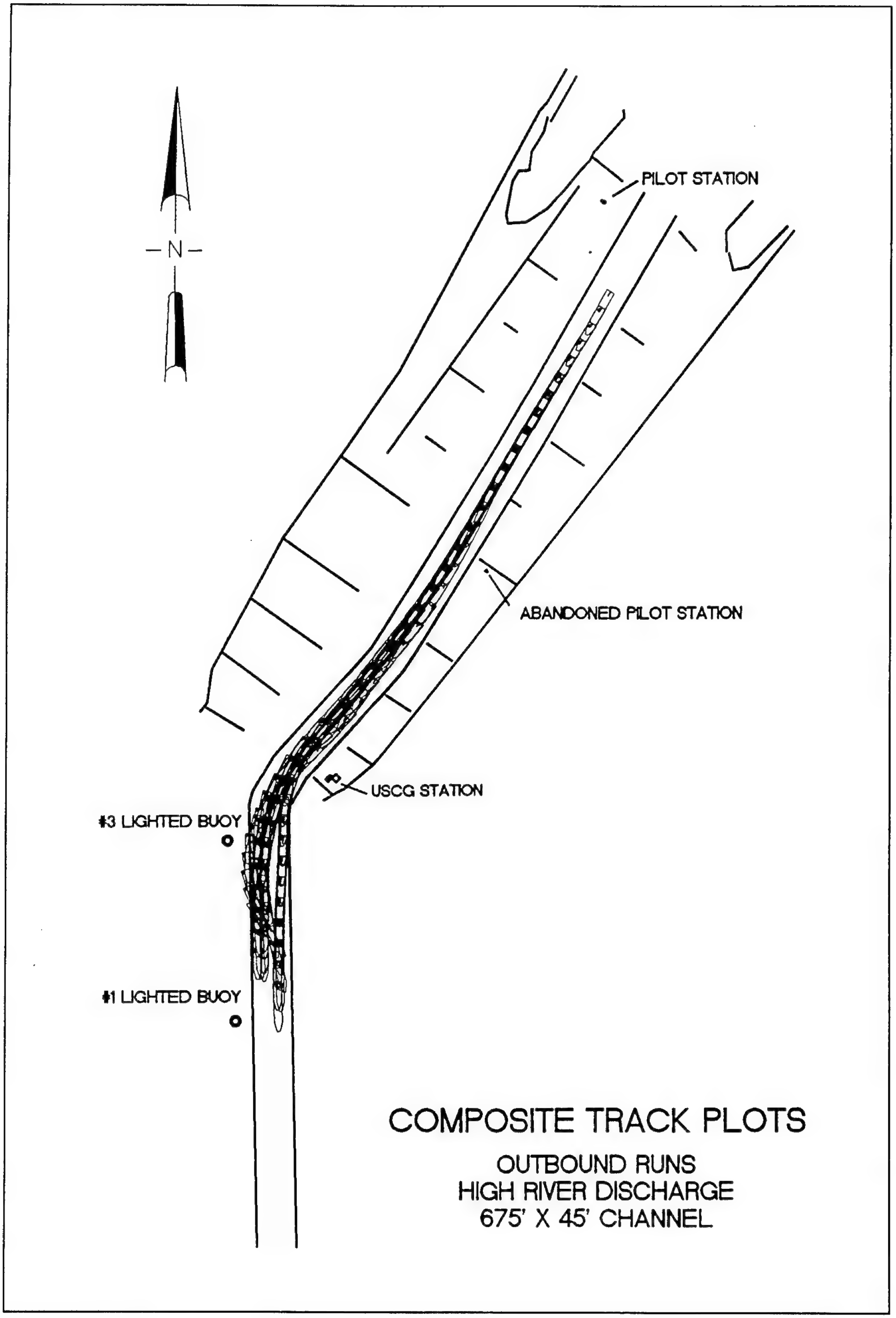

N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
OUTBOUND RUNS
HIGH RIVER DISCHARGE
600' X 40' CHANNEL

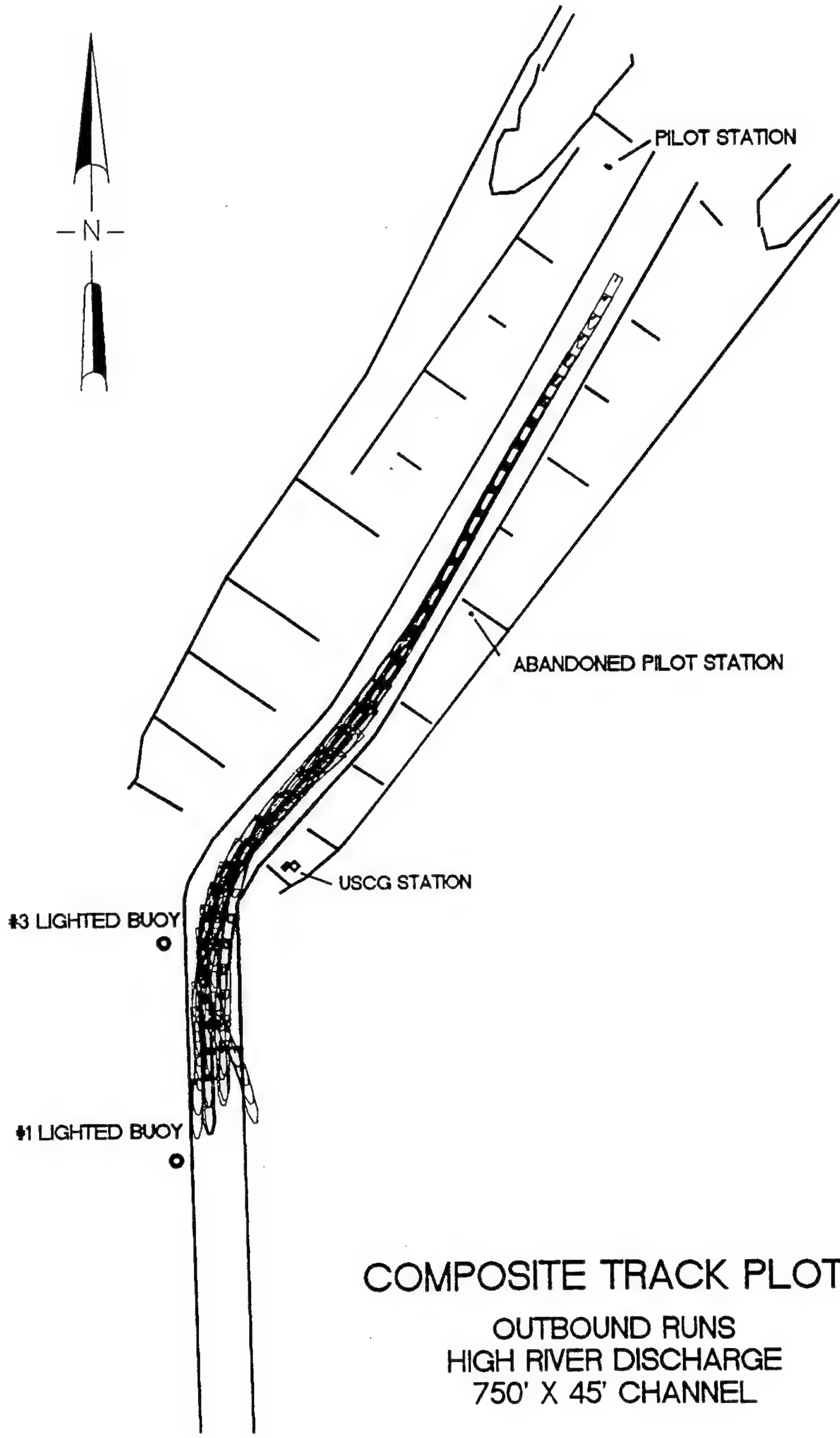
Plate 6


N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
OUTBOUND RUNS
HIGH RIVER DISCHARGE
600' X 45' CHANNEL



N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
OUTBOUND RUNS
HIGH RIVER DISCHARGE
675' X 45' CHANNEL

Plate 8



COMPOSITE TRACK PLOTS

OUTBOUND RUNS
HIGH RIVER DISCHARGE
750' X 45' CHANNEL

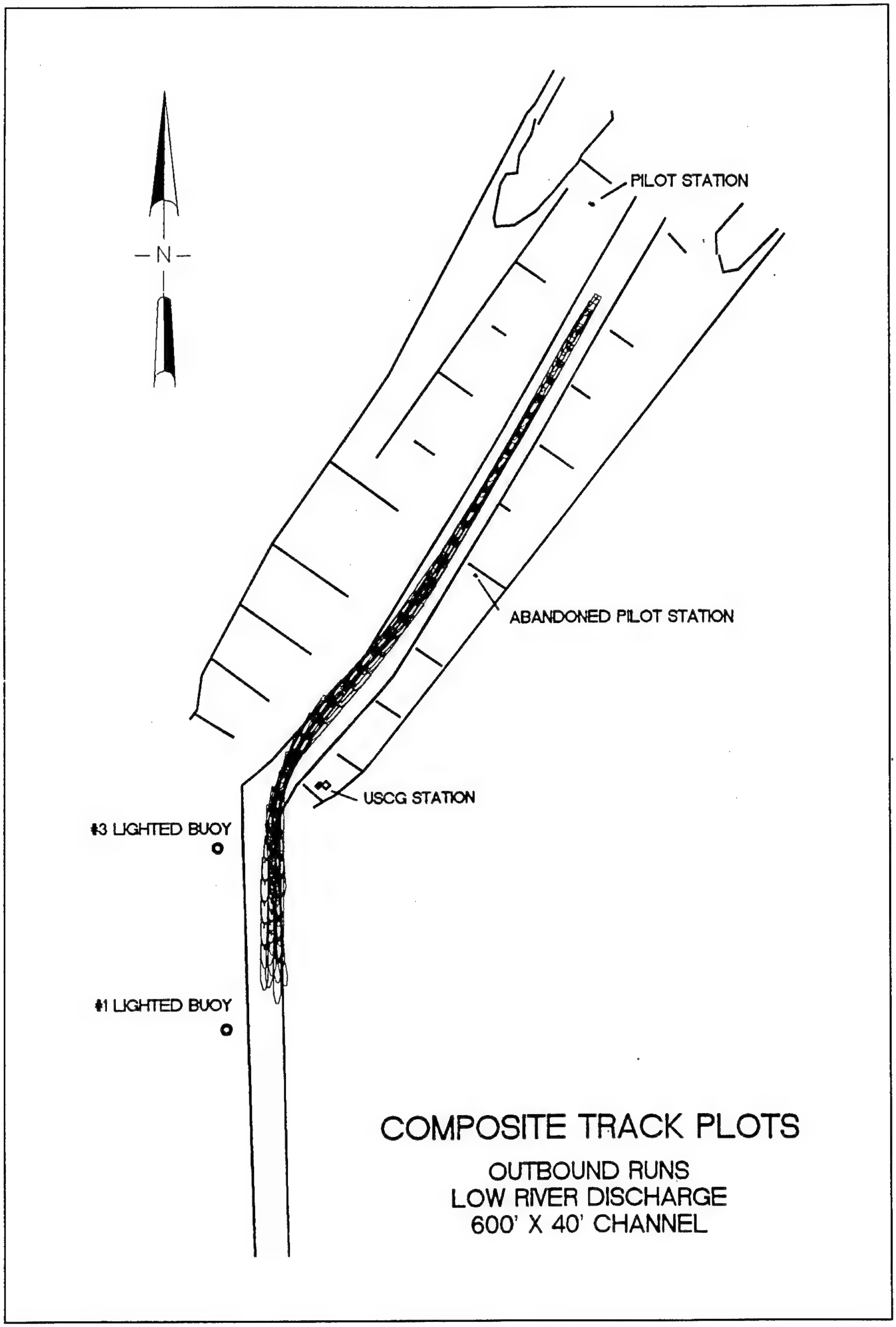
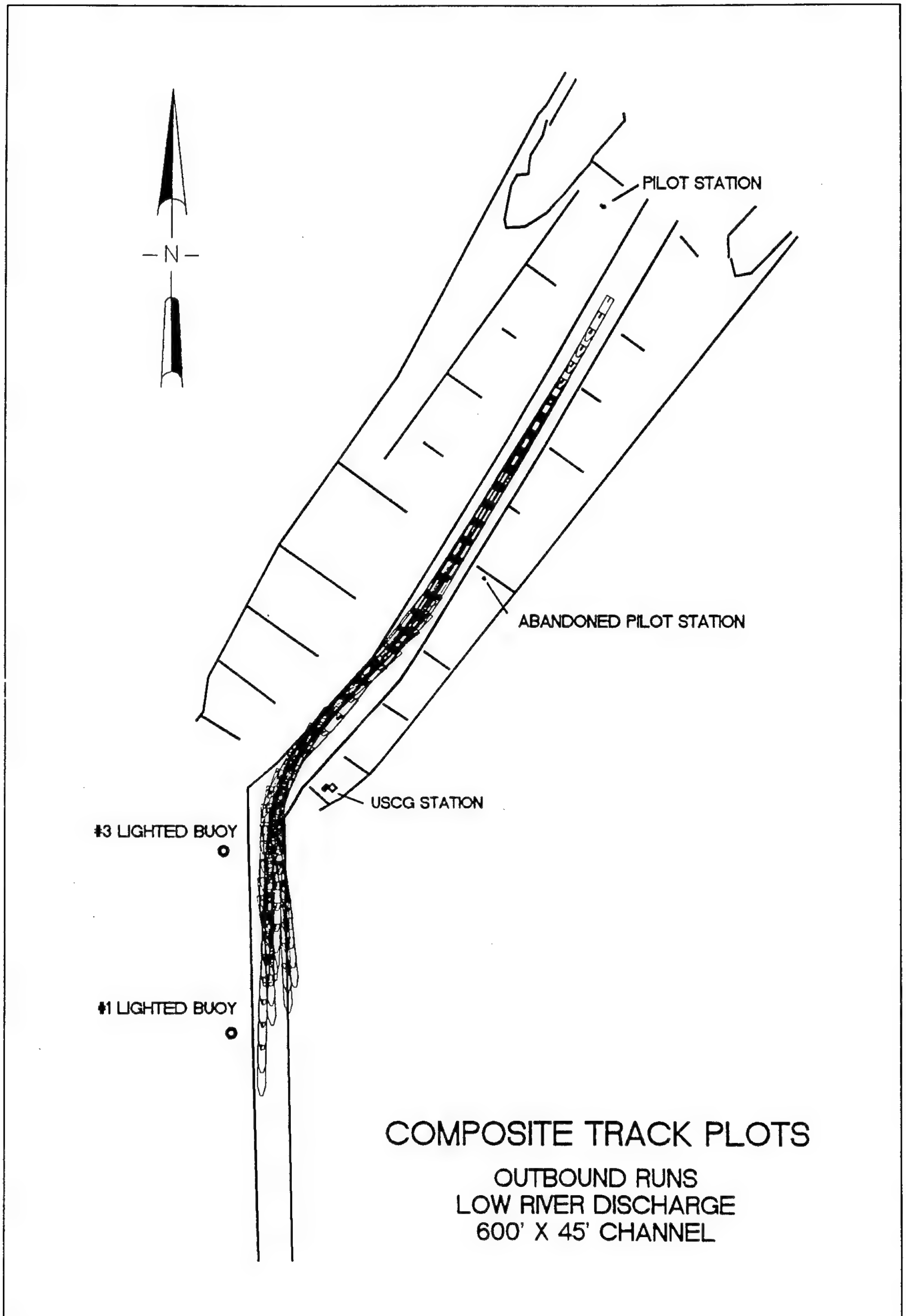

N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
OUTBOUND RUNS
LOW RIVER DISCHARGE
600' X 40' CHANNEL

Plate 10



COMPOSITE TRACK PLOTS

OUTBOUND RUNS
LOW RIVER DISCHARGE
600' X 45' CHANNEL

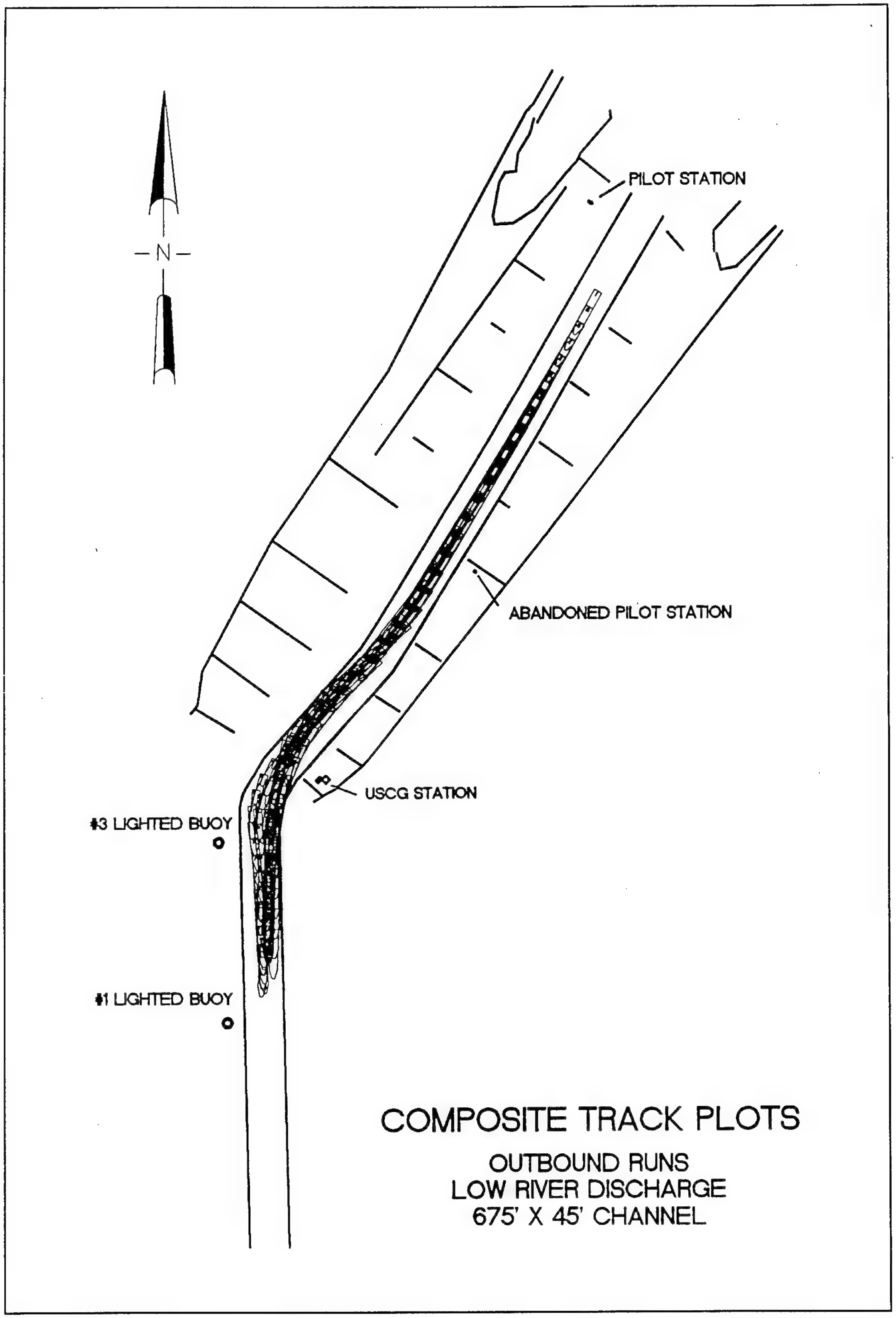
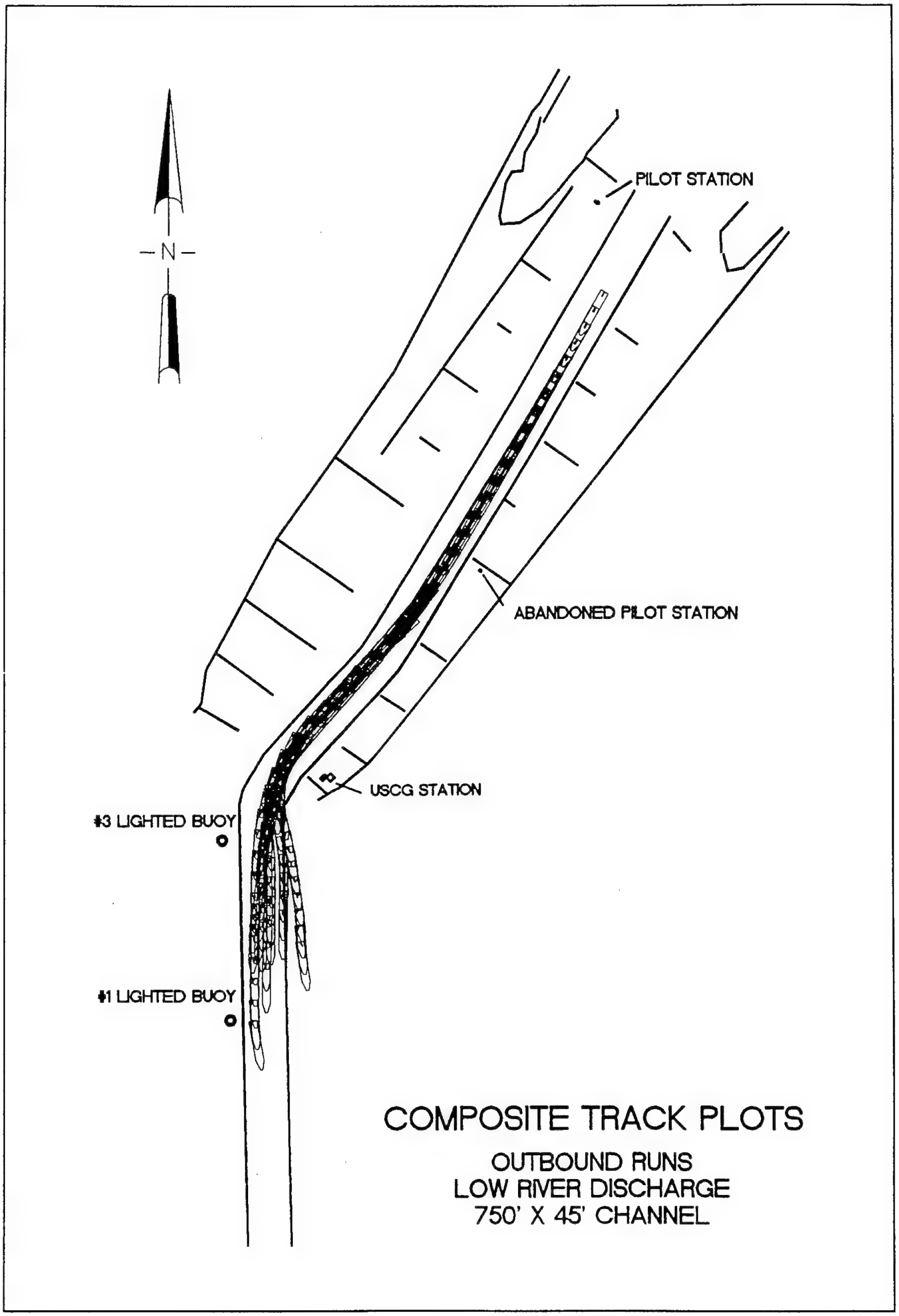

N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
OUTBOUND RUNS
LOW RIVER DISCHARGE
675' X 45' CHANNEL

Plate 12


N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
OUTBOUND RUNS
LOW RIVER DISCHARGE
750' X 45' CHANNEL

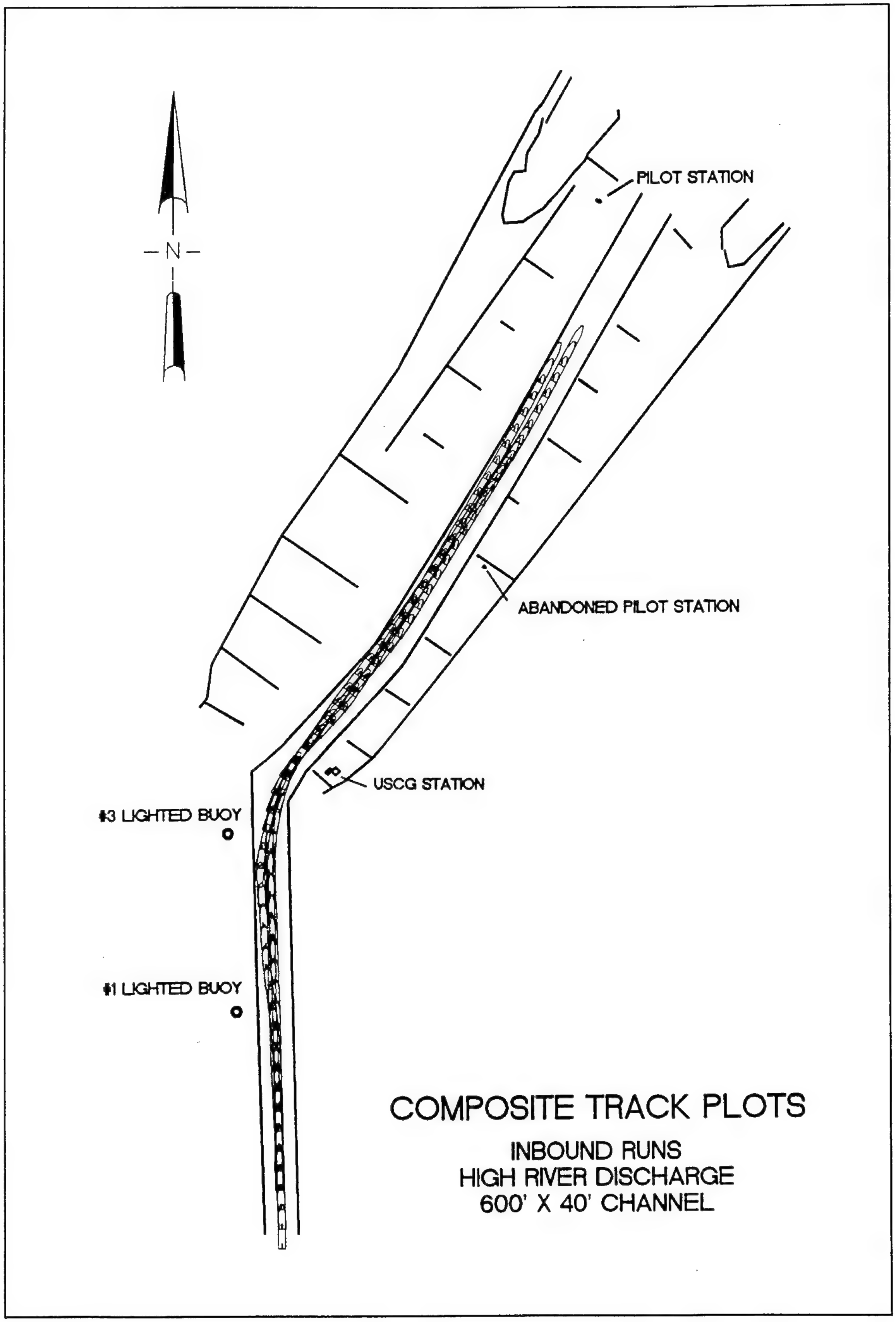

PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND RUNS
HIGH RIVER DISCHARGE
600' X 40' CHANNEL

Plate 14

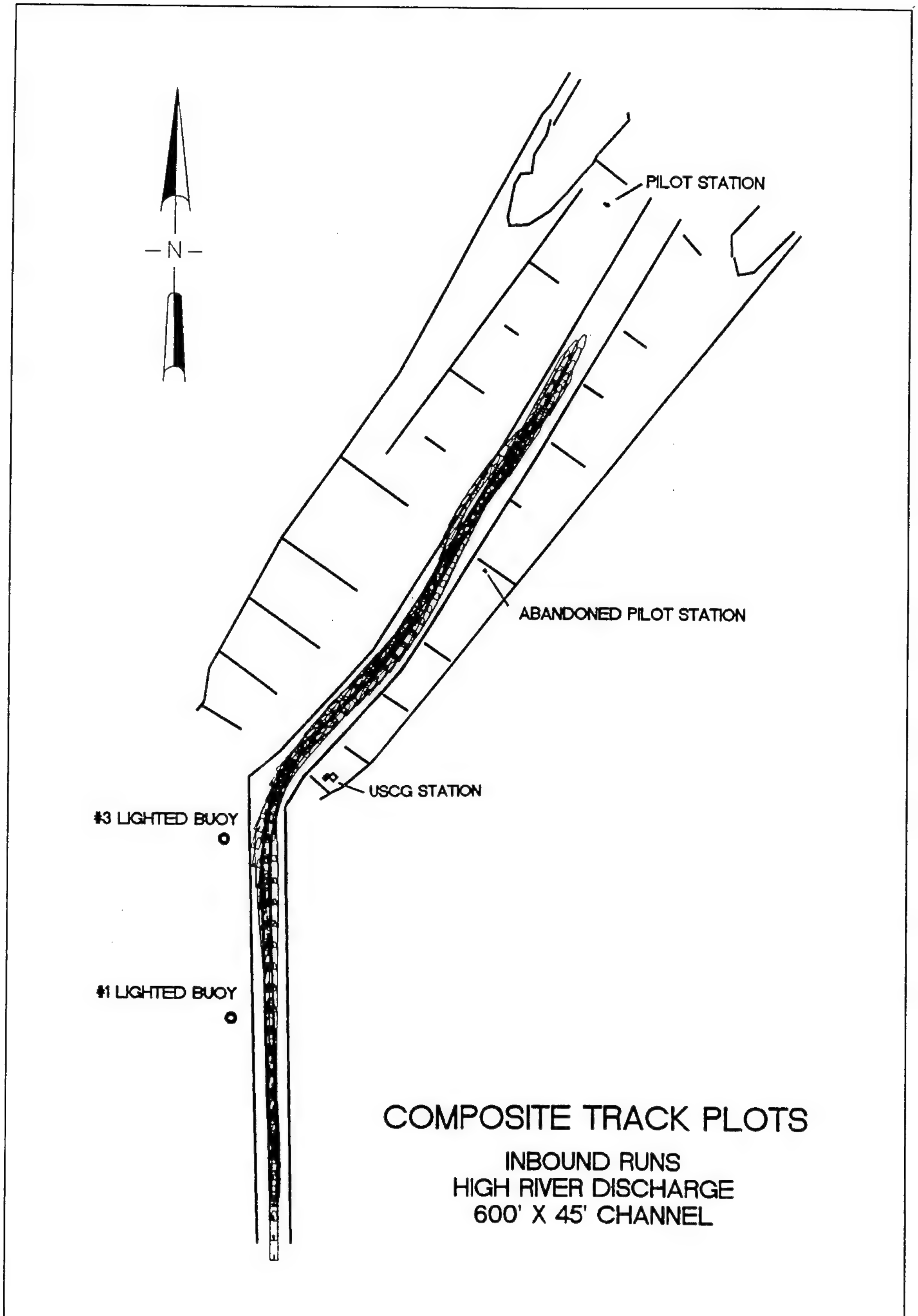
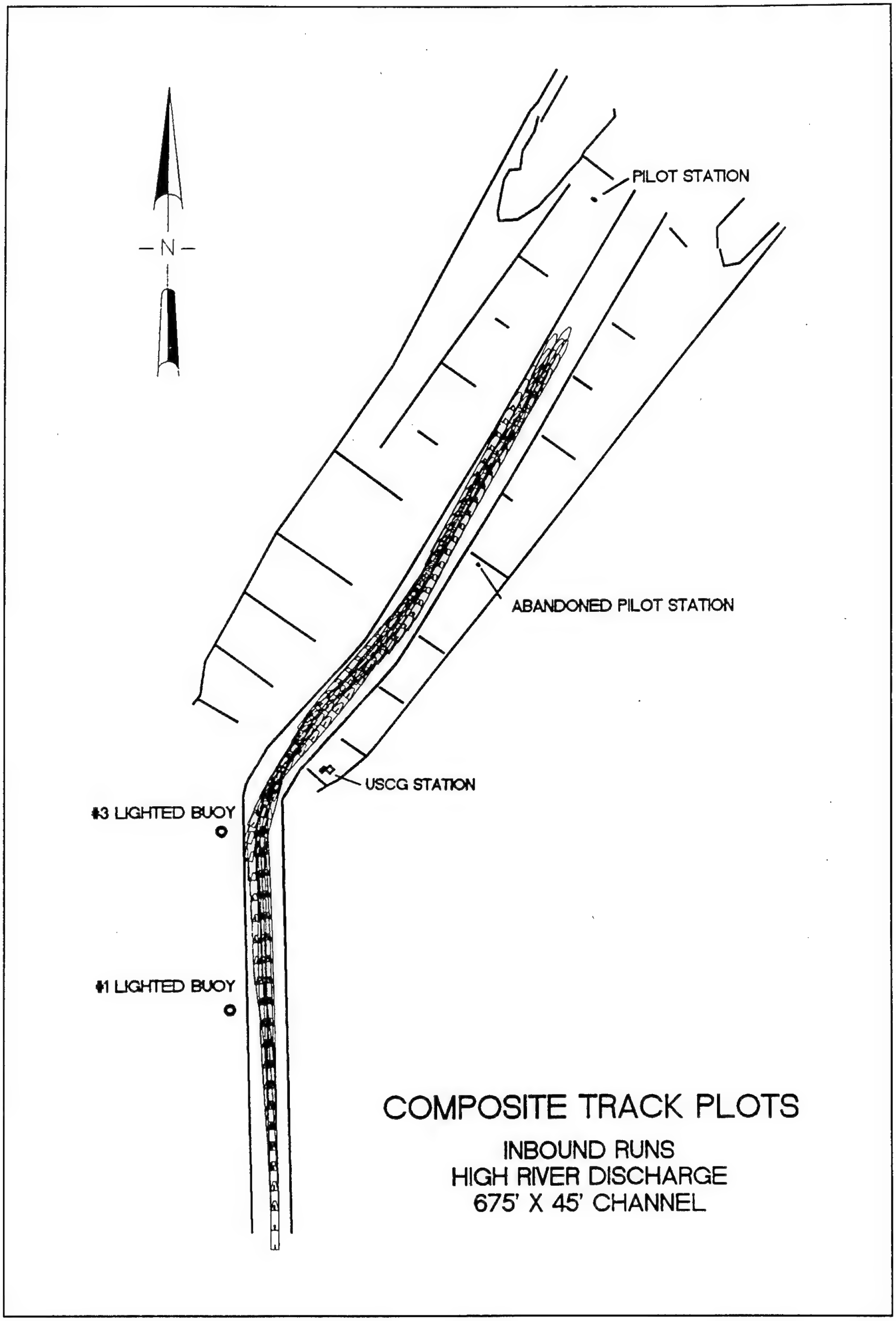
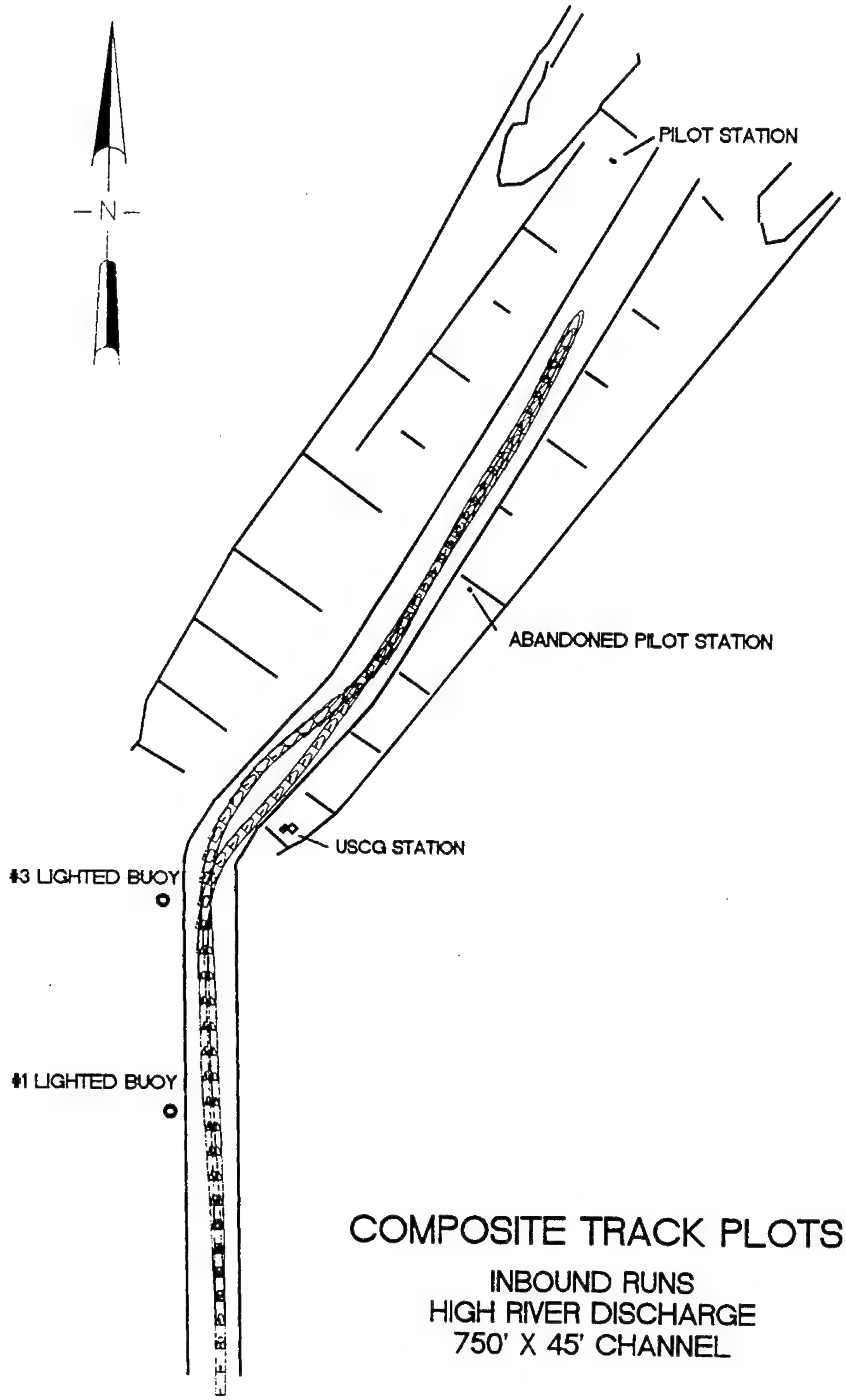

PILOT STATION
N
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND RUNS
HIGH RIVER DISCHARGE
600' X 45' CHANNEL

Plate 15



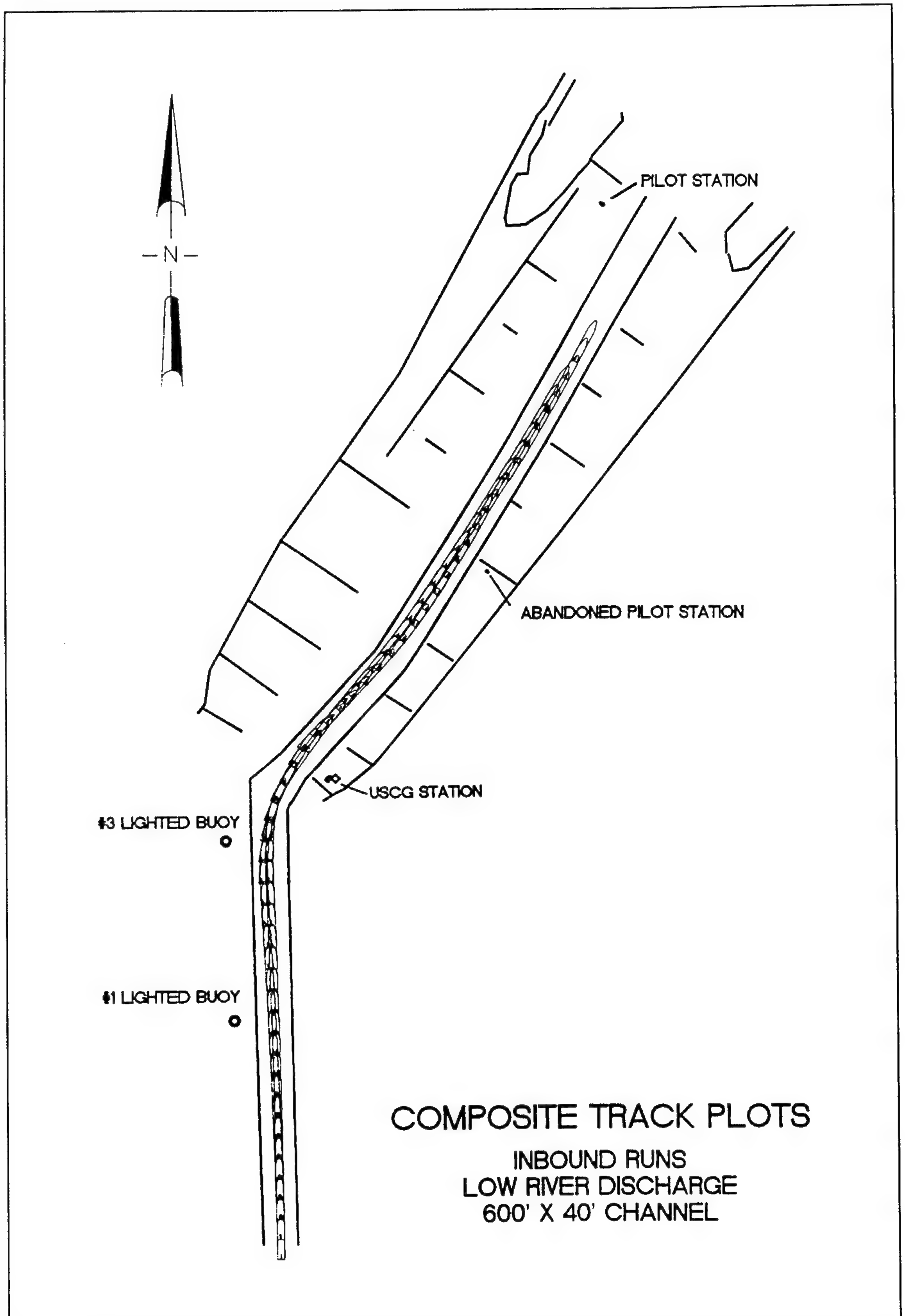
N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND RUNS
HIGH RIVER DISCHARGE
675' X 45' CHANNEL

Plate 16



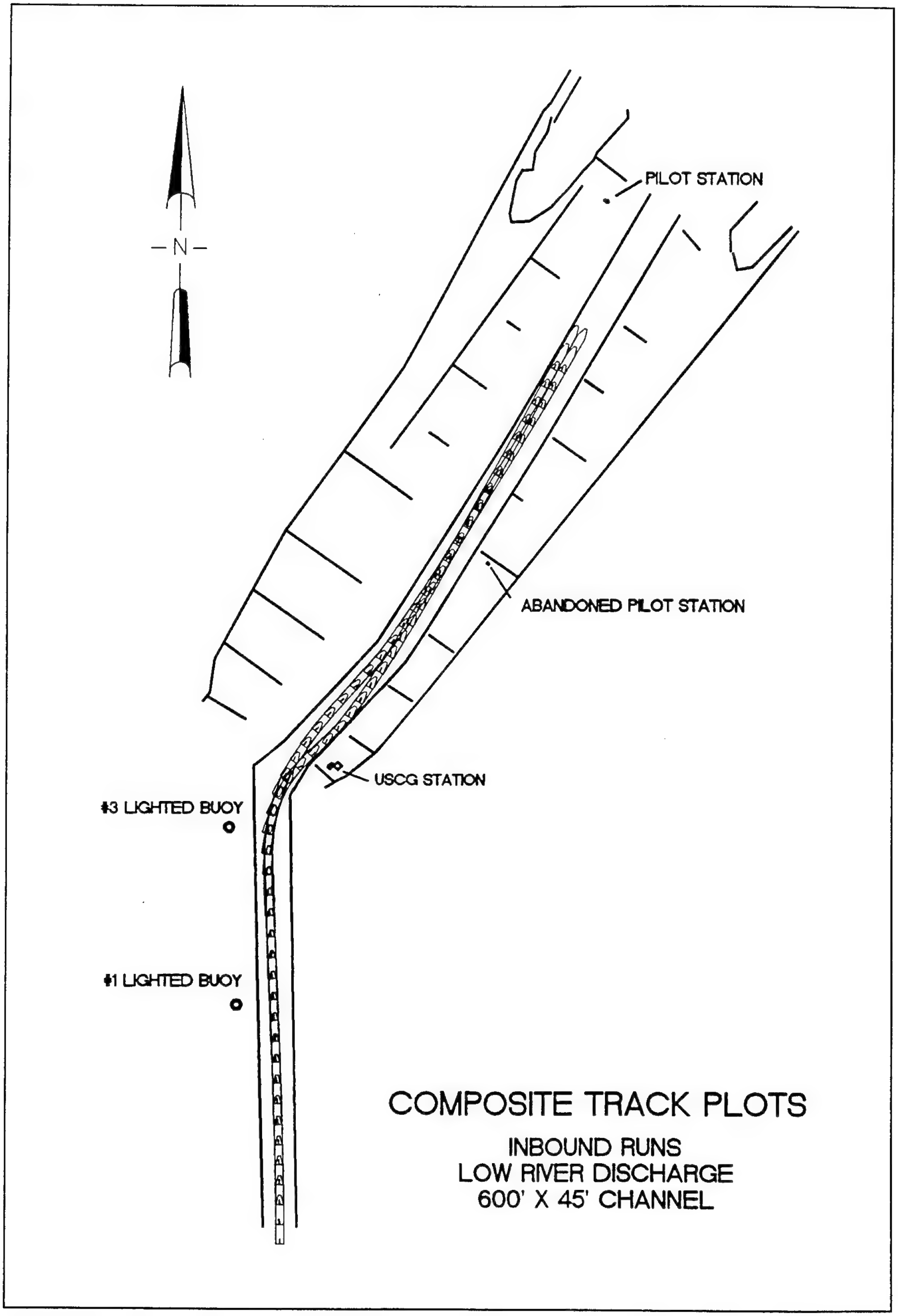
COMPOSITE TRACK PLOTS

INBOUND RUNS
HIGH RIVER DISCHARGE
750' X 45' CHANNEL



N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND RUNS
LOW RIVER DISCHARGE
600' X 40' CHANNEL

Plate 18


PILOT STATION
N
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND RUNS
LOW RIVER DISCHARGE
600' X 45' CHANNEL

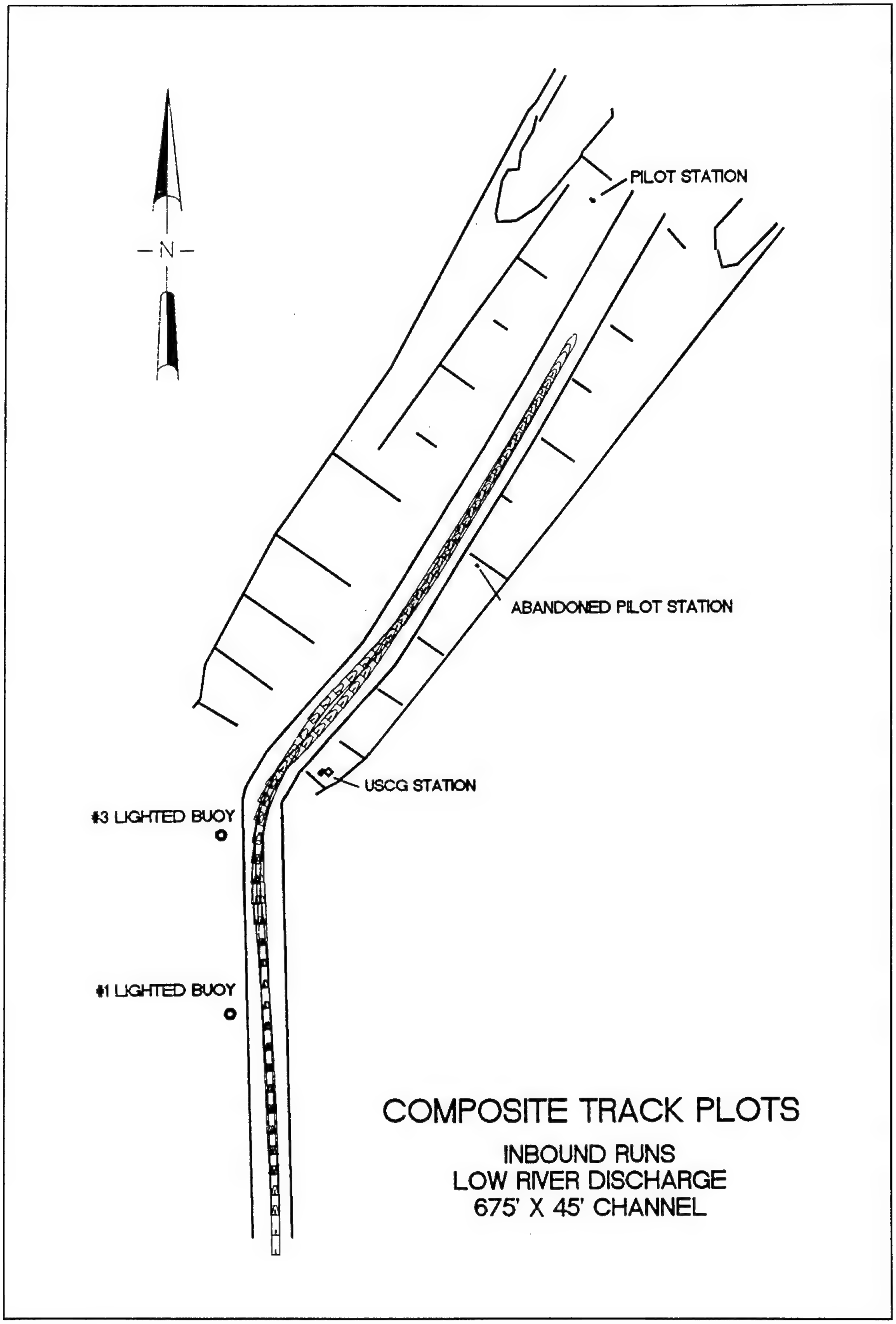
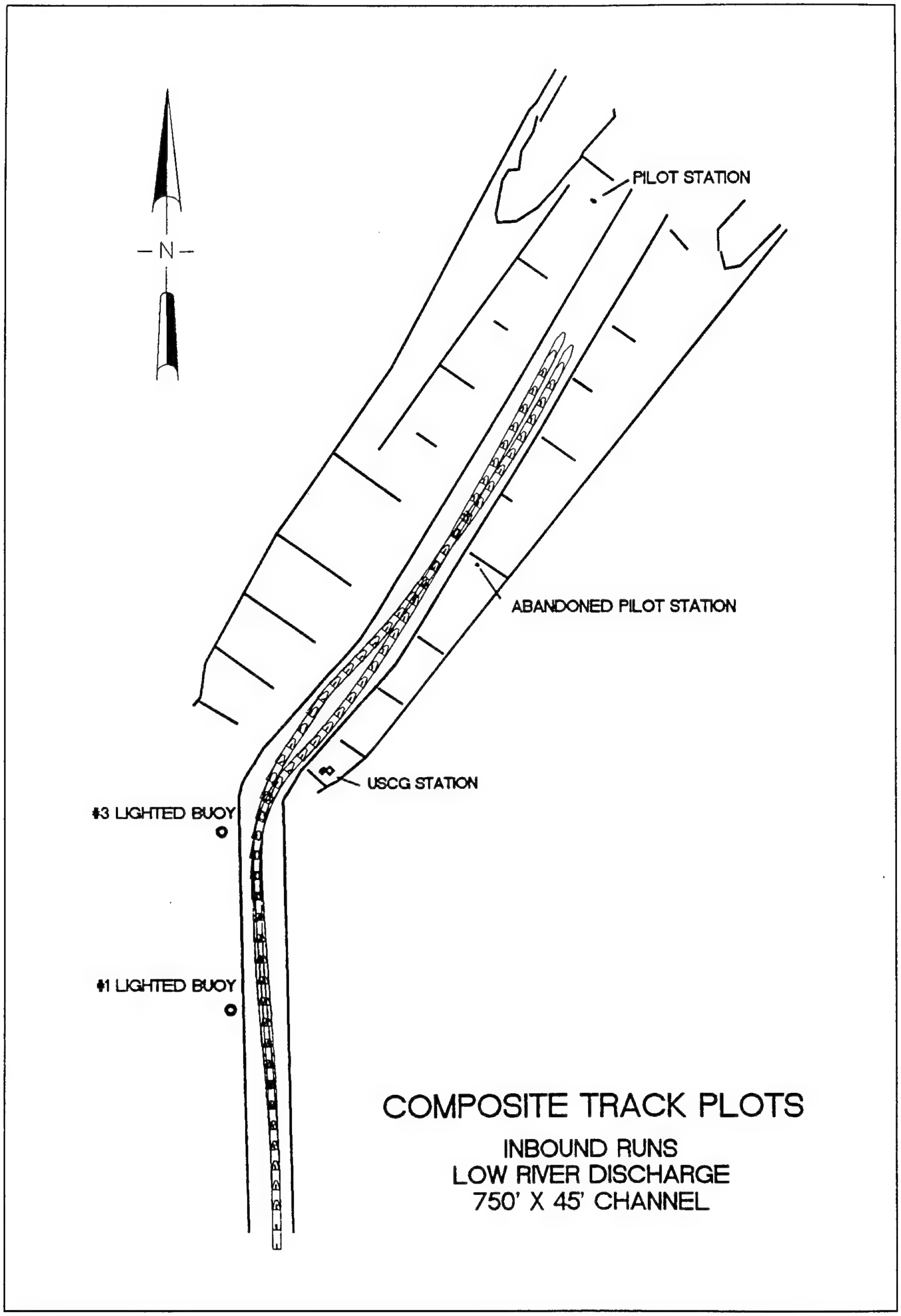
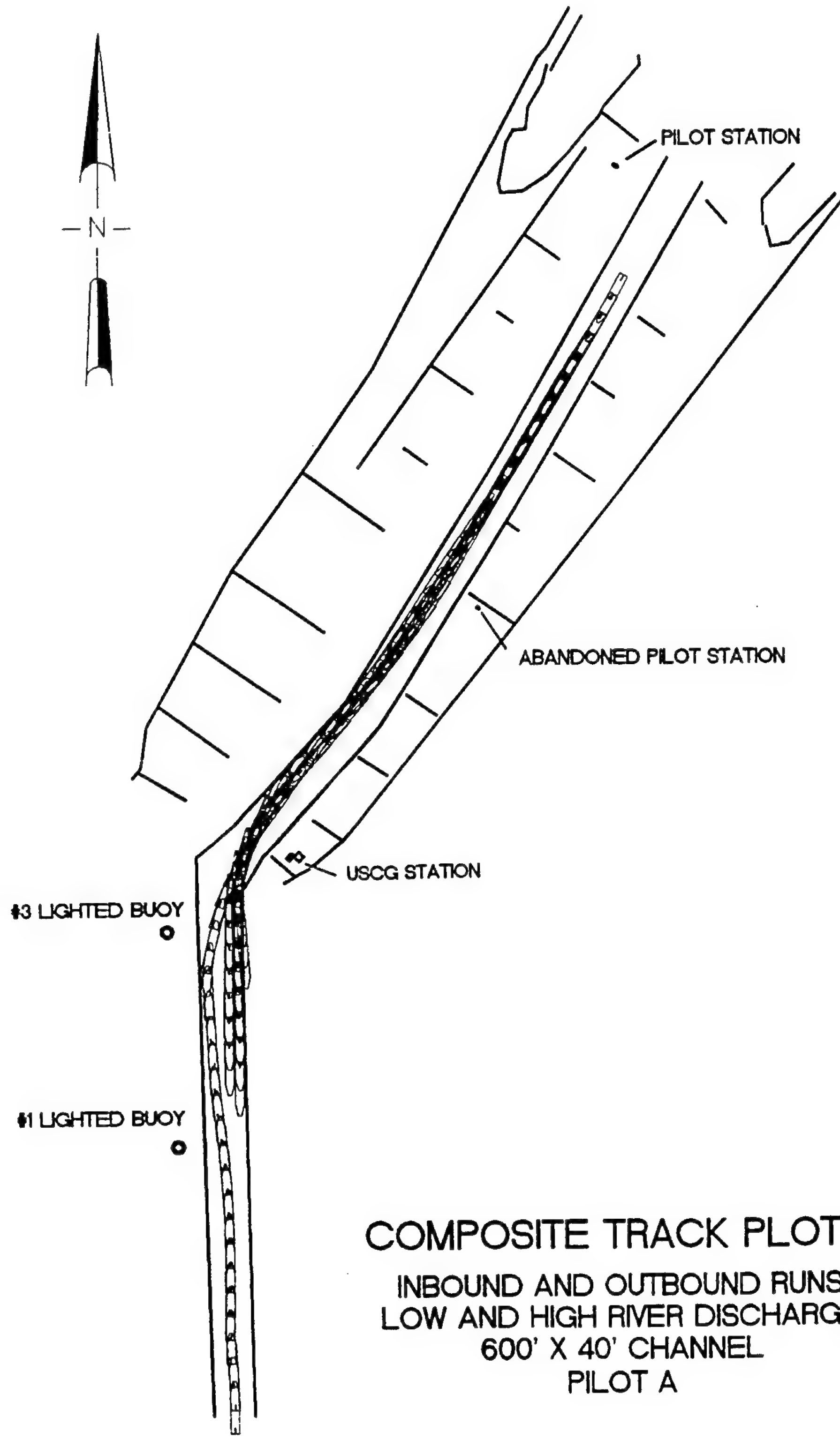

N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND RUNS
LOW RIVER DISCHARGE
675' X 45' CHANNEL

Plate 20

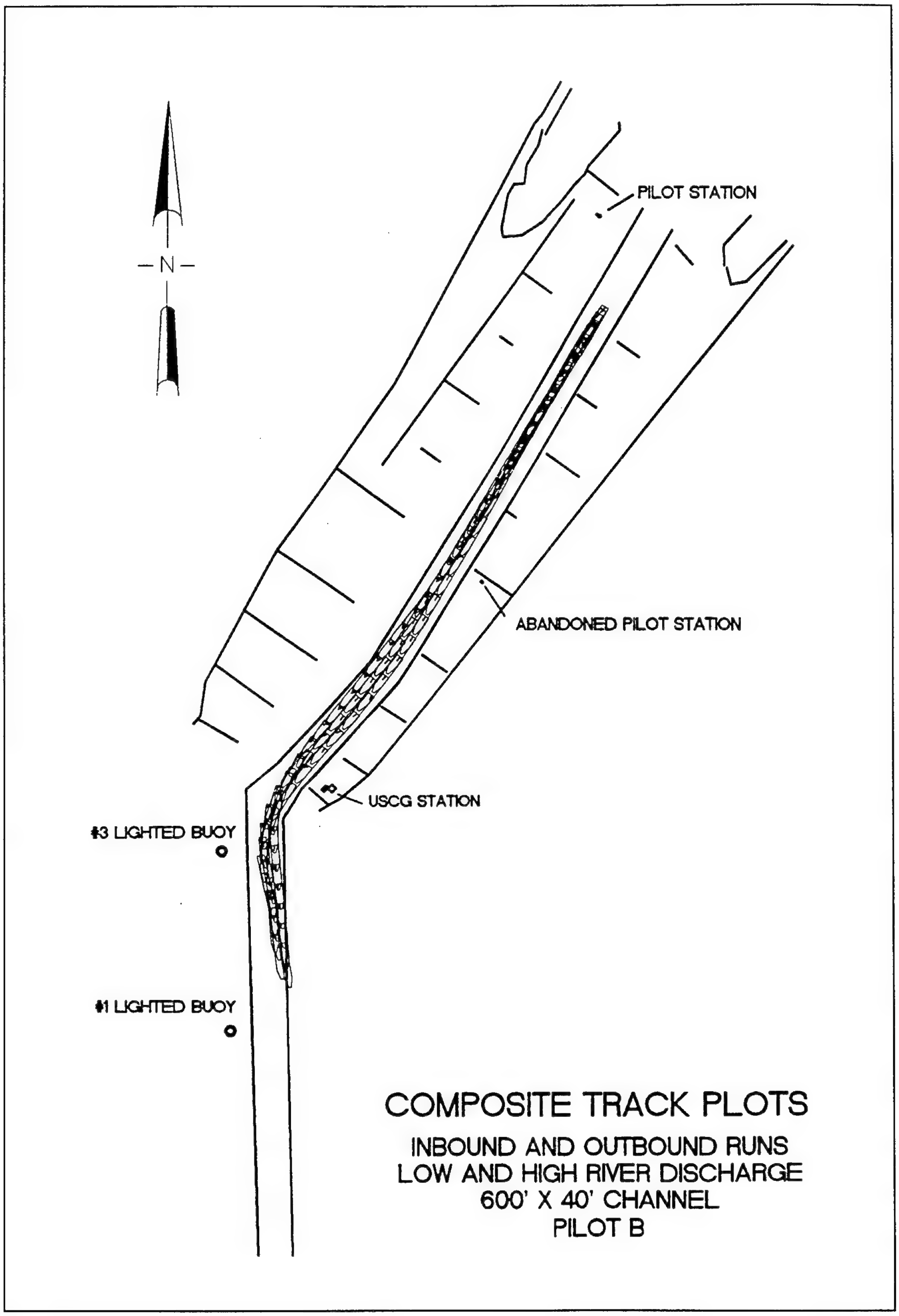

N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND RUNS
LOW RIVER DISCHARGE
750' X 45' CHANNEL



COMPOSITE TRACK PLOTS

INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
600' X 40' CHANNEL
PILOT A

Plate 22



N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
600' X 40' CHANNEL
PILOT B

Plate 23

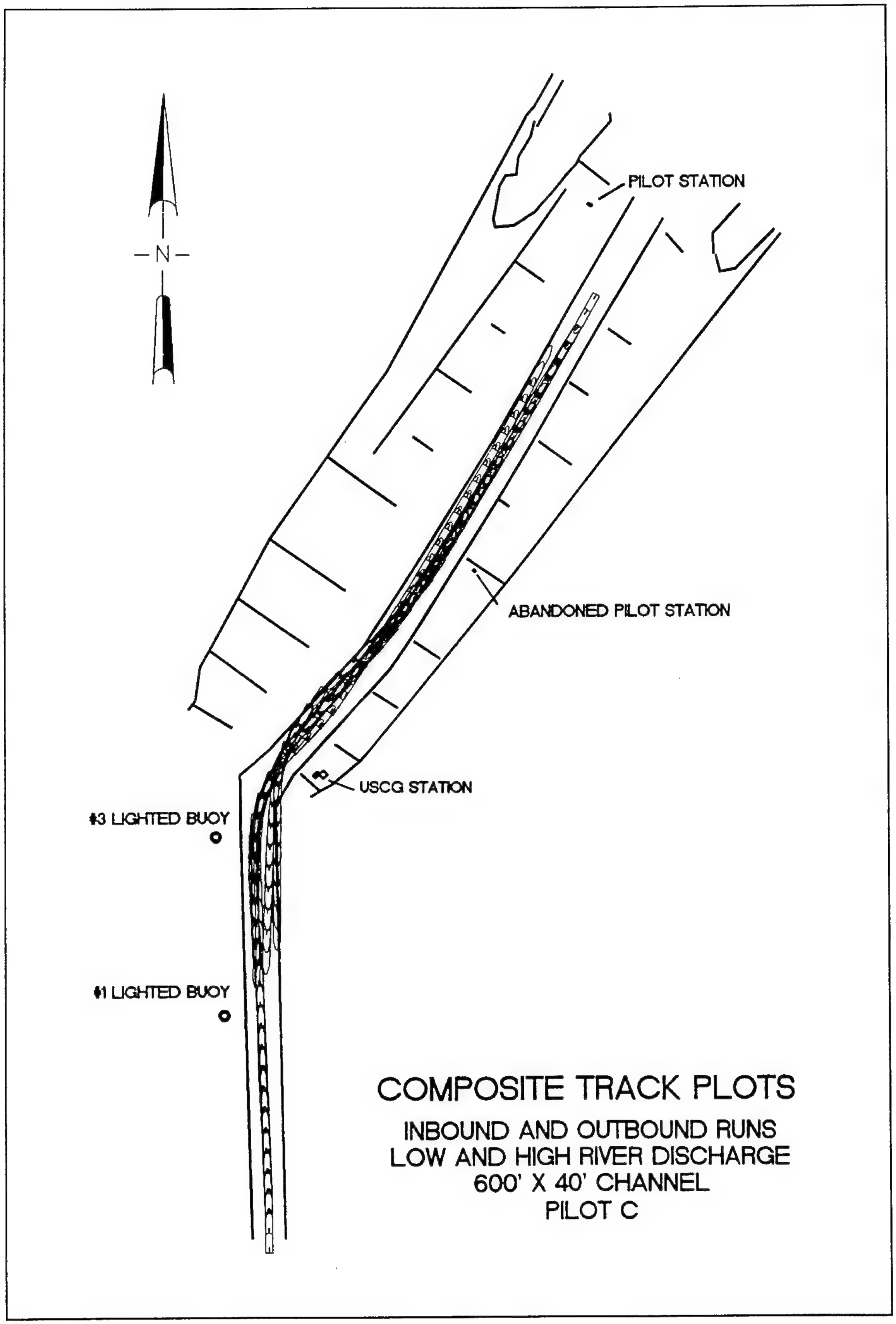
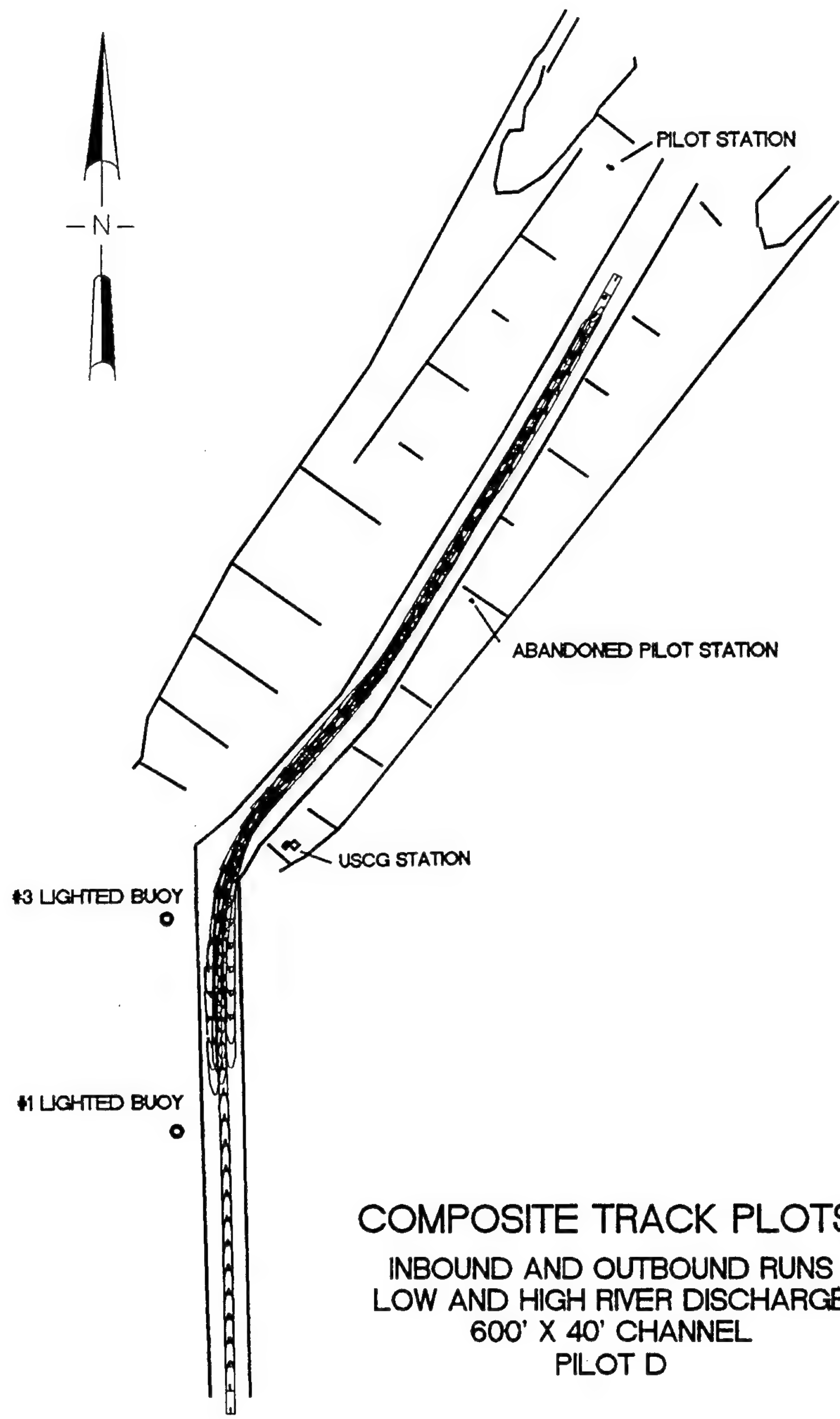

N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
600' X 40' CHANNEL
PILOT C

Plate 24



COMPOSITE TRACK PLOTS

INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
600' X 40' CHANNEL
PILOT D

Plate 25

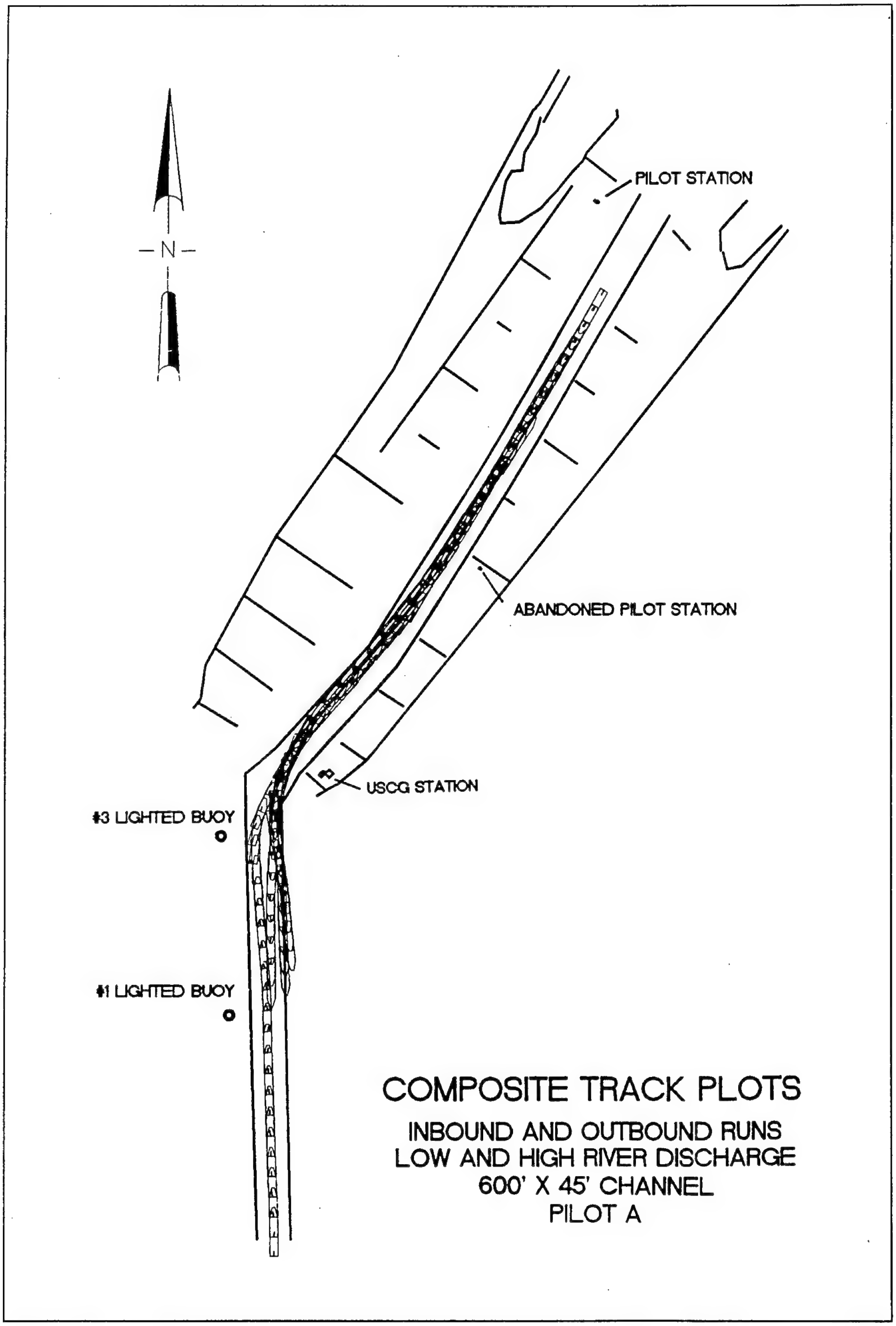
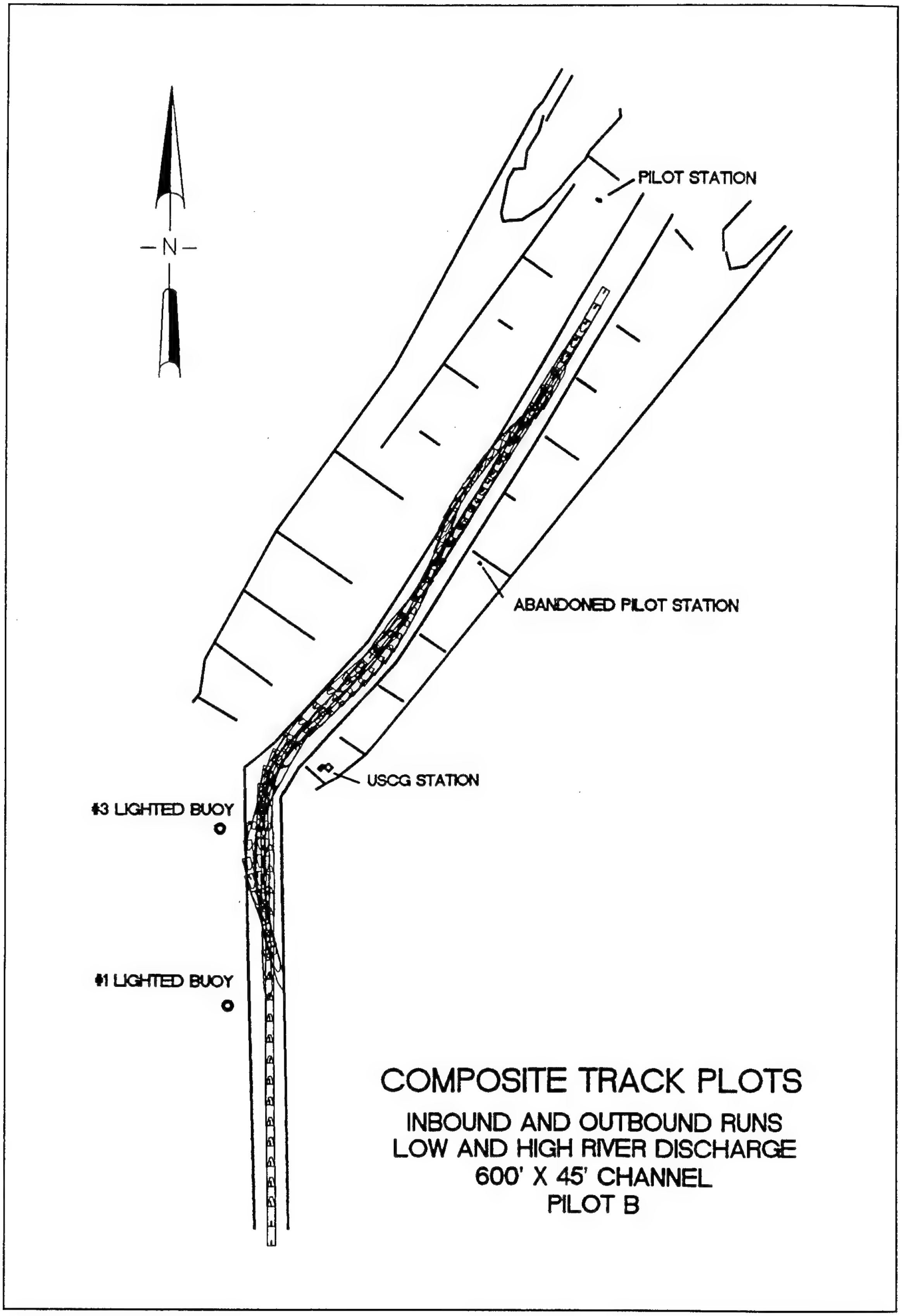
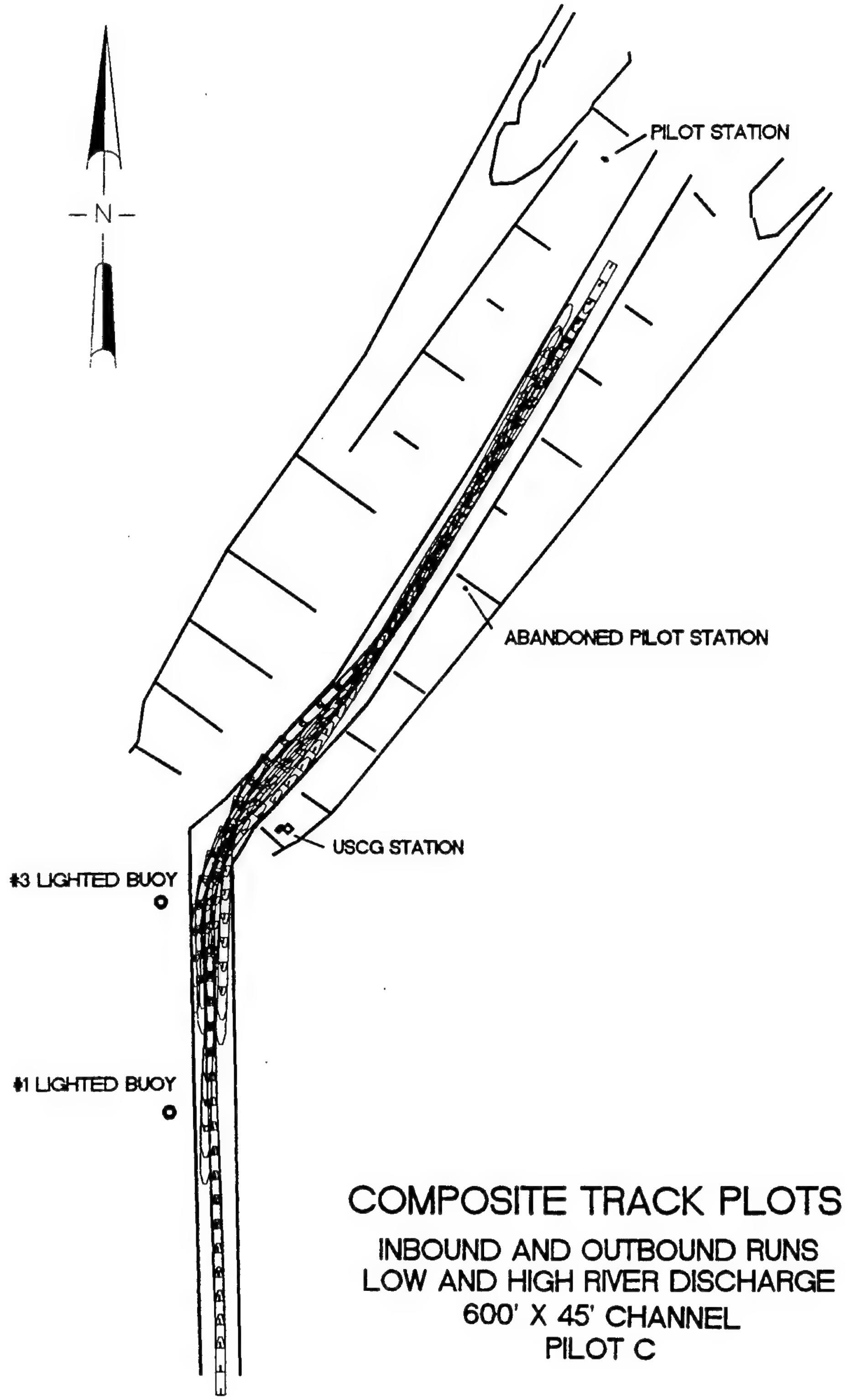

PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
N
COMPOSITE TRACK PLOTS
INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
600' X 45' CHANNEL
PILOT A

Plate 26

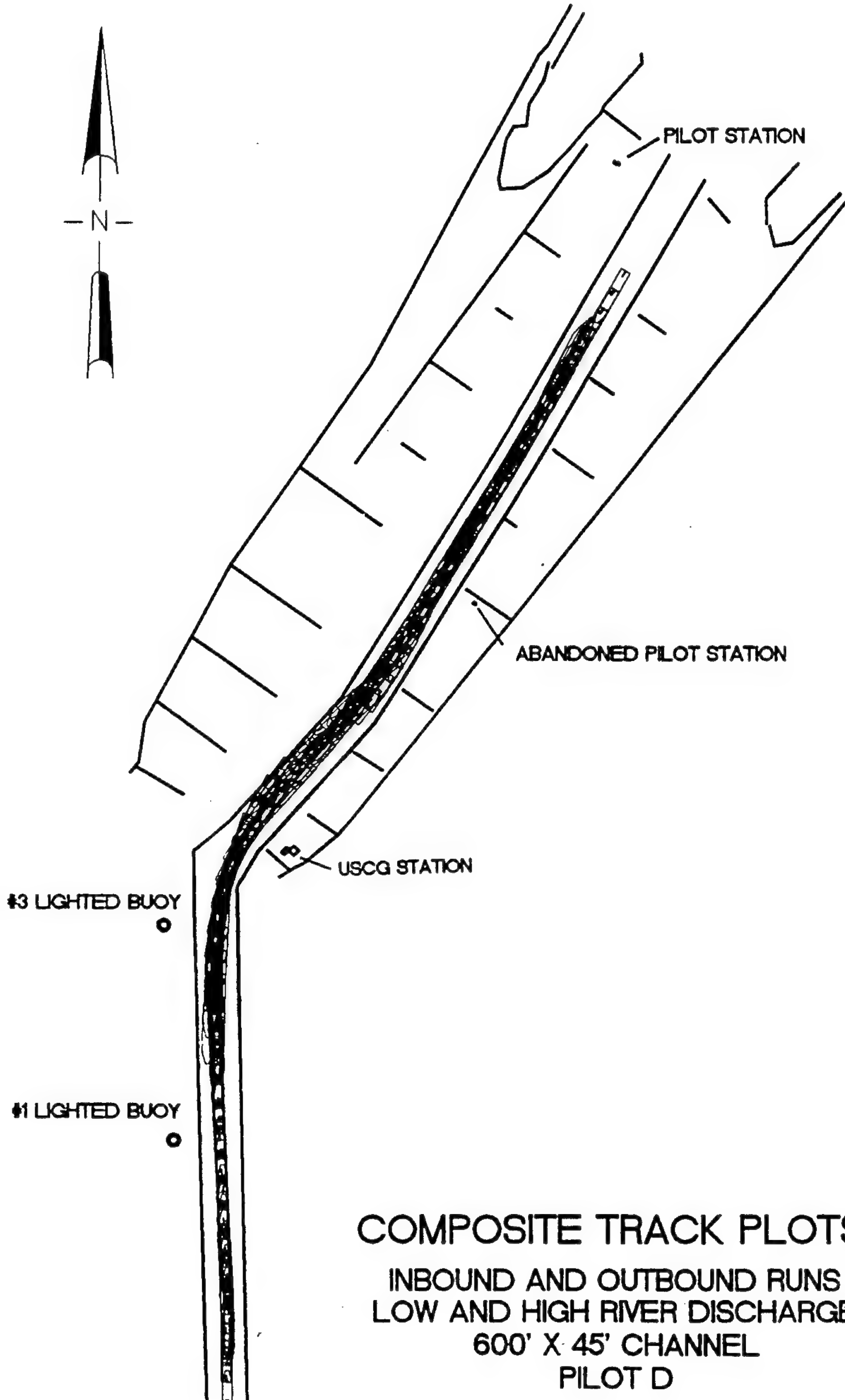


N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
600' X 45' CHANNEL
PILOT B

Plate 27



COMPOSITE TRACK PLOTS
INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
600' X 45' CHANNEL
PILOT C



COMPOSITE TRACK PLOTS
INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
600' X 45' CHANNEL
PILOT D

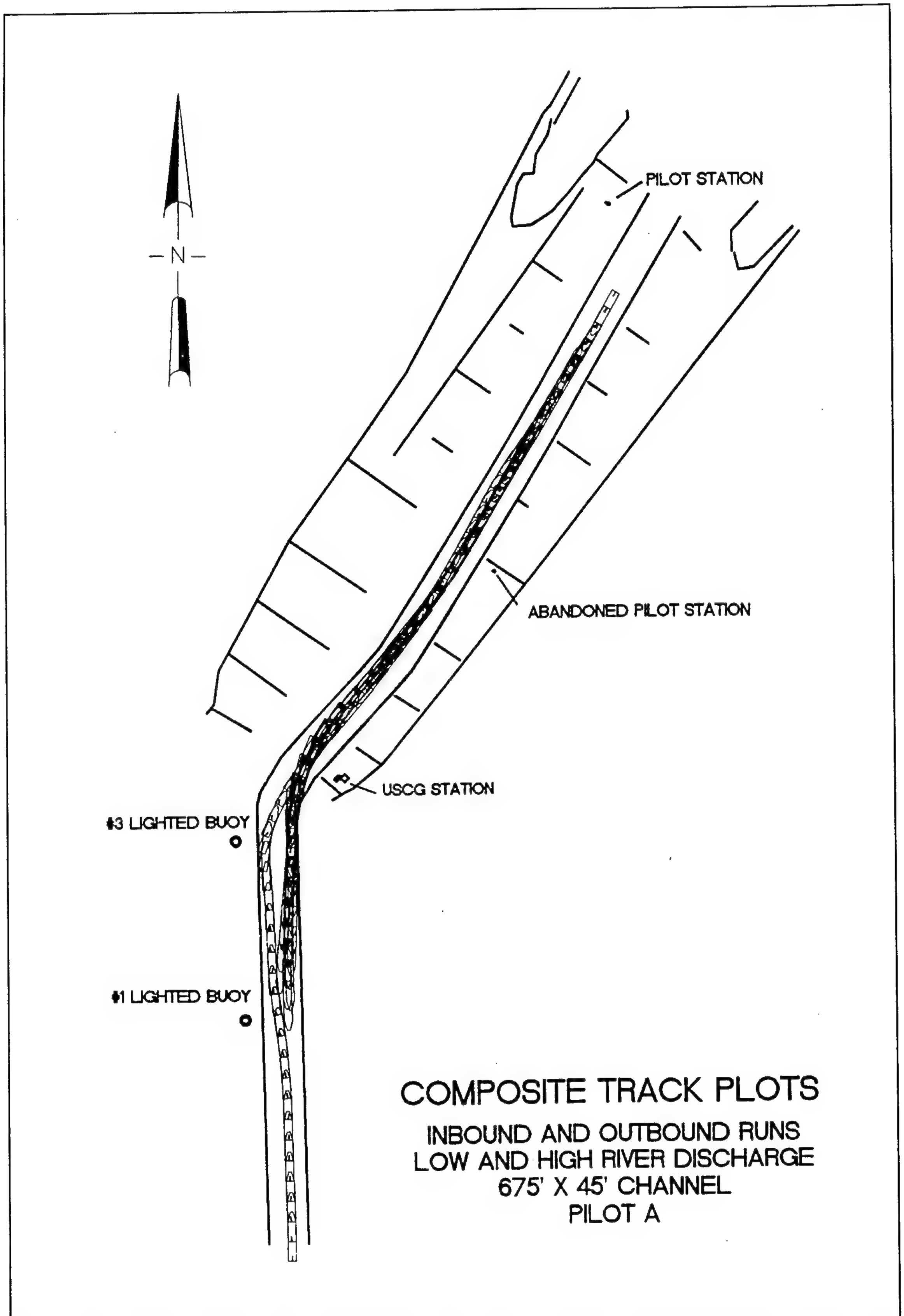
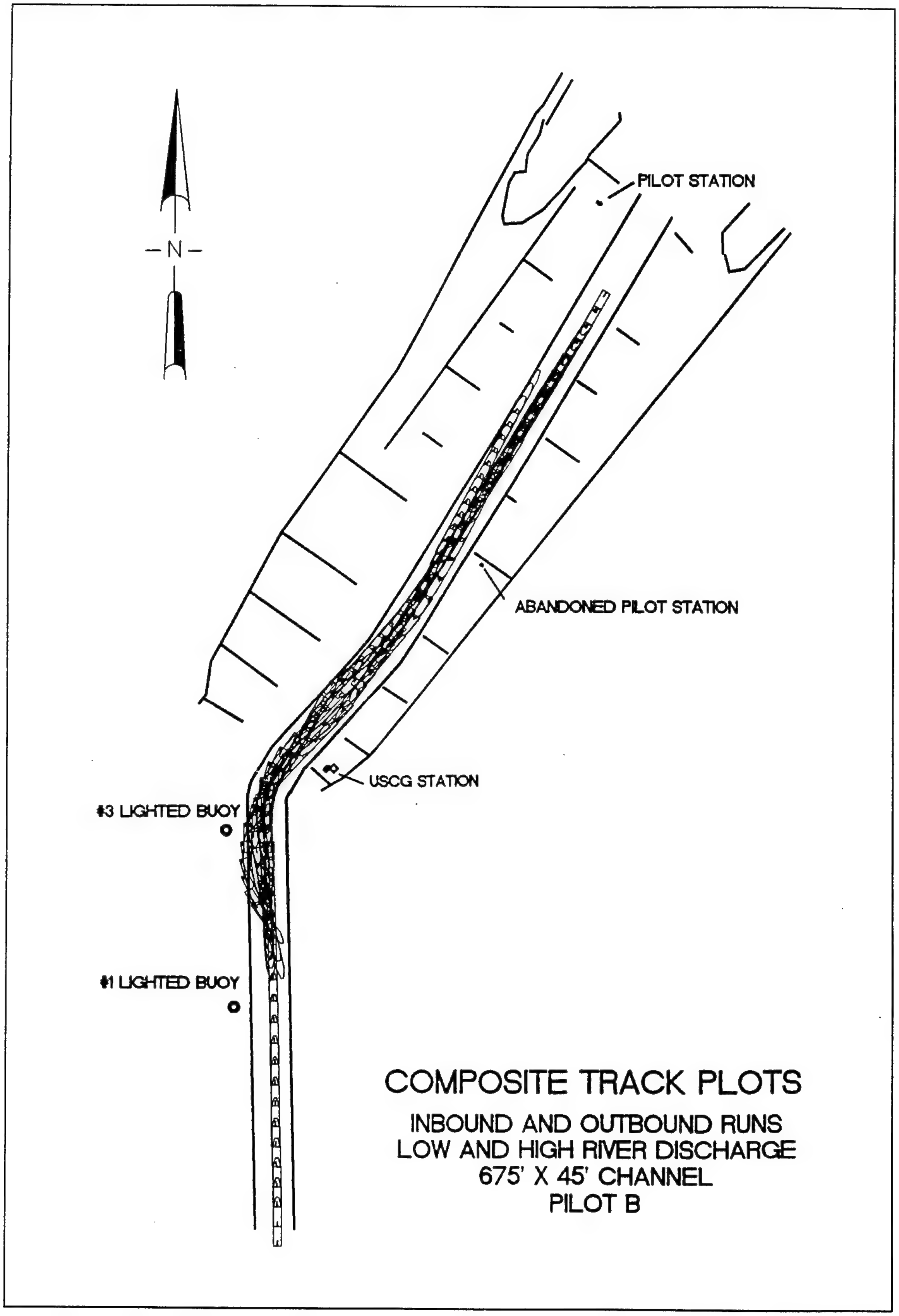
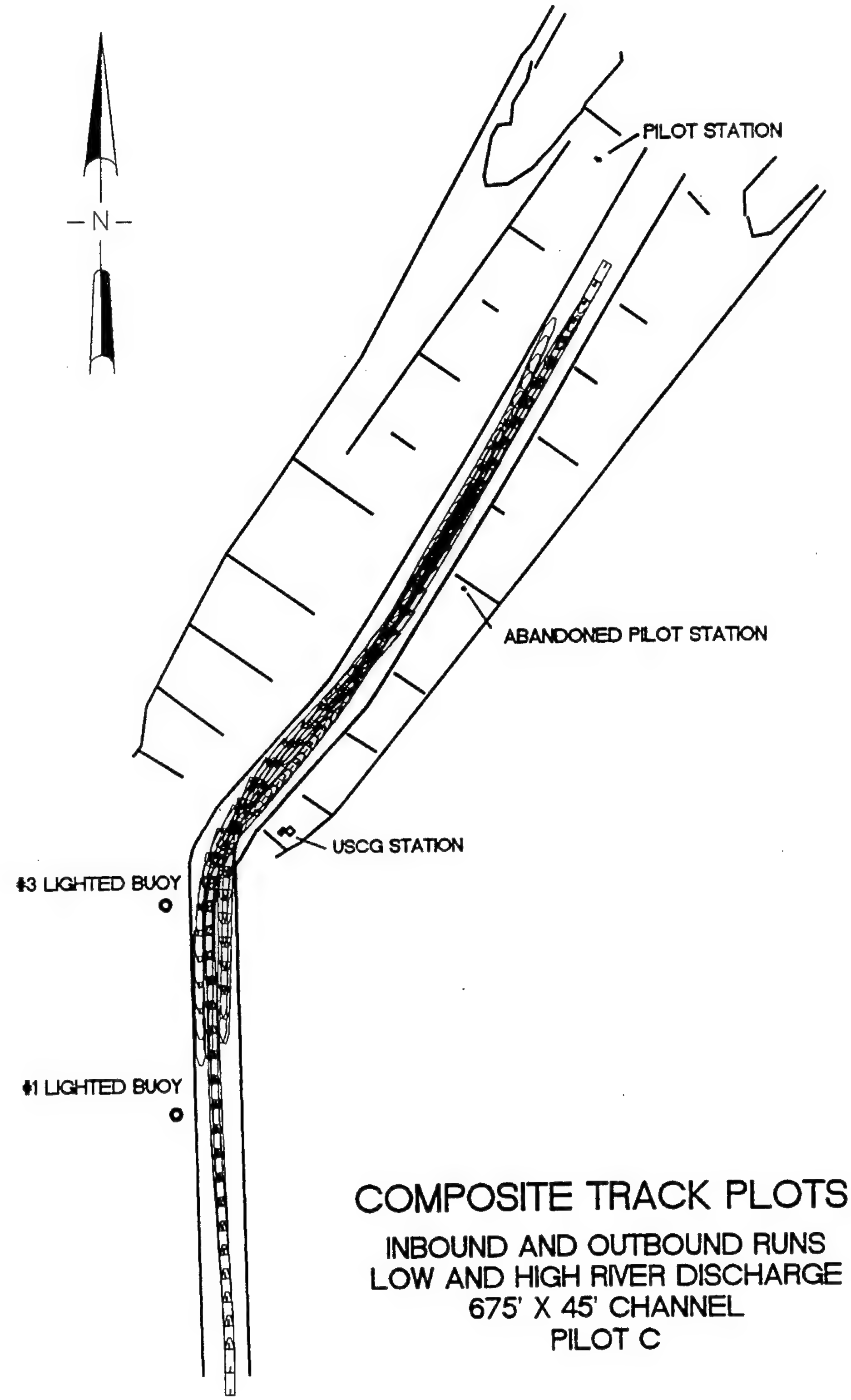

N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
675' X 45' CHANNEL
PILOT A

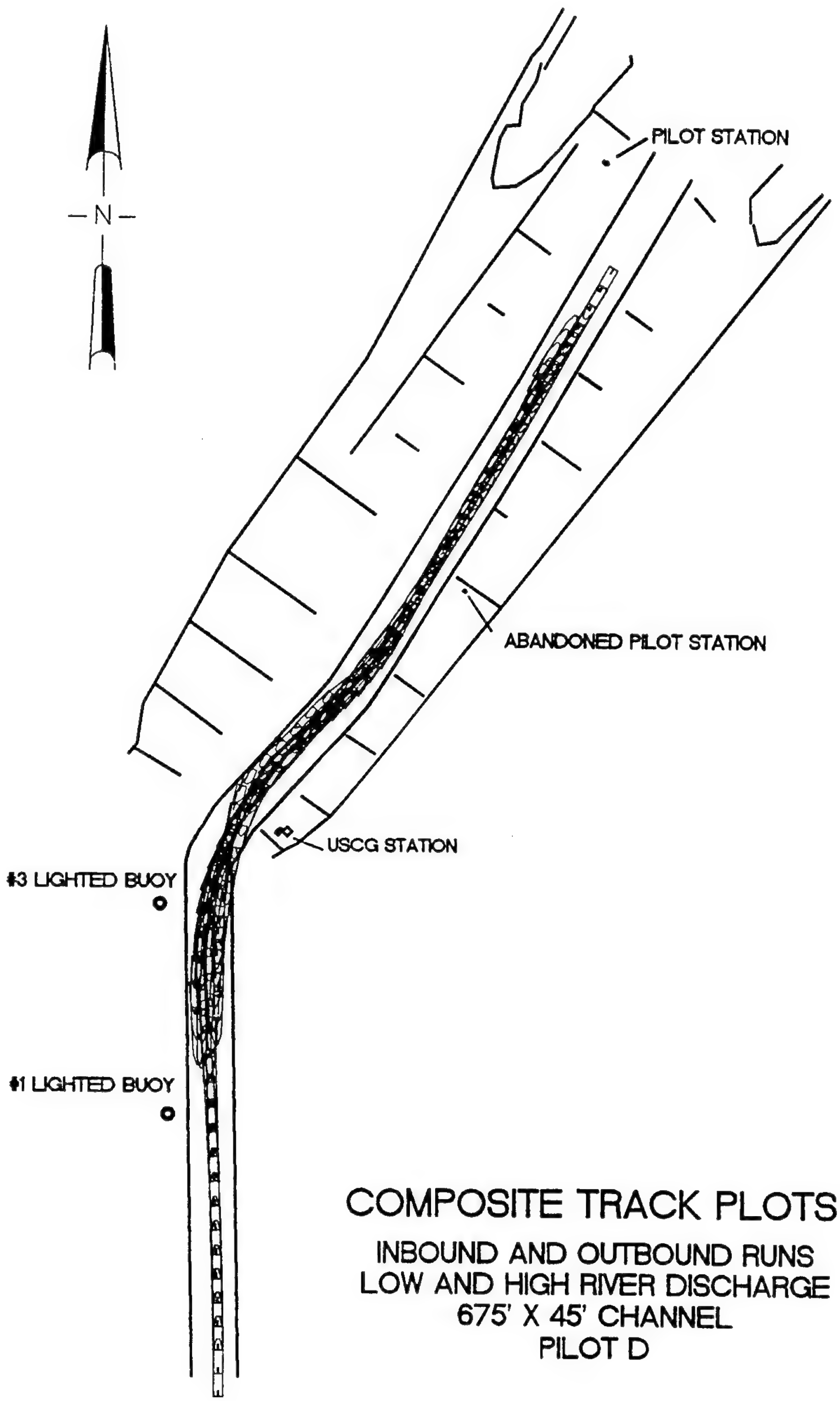
Plate 30


N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
675' X 45' CHANNEL
PILOT B

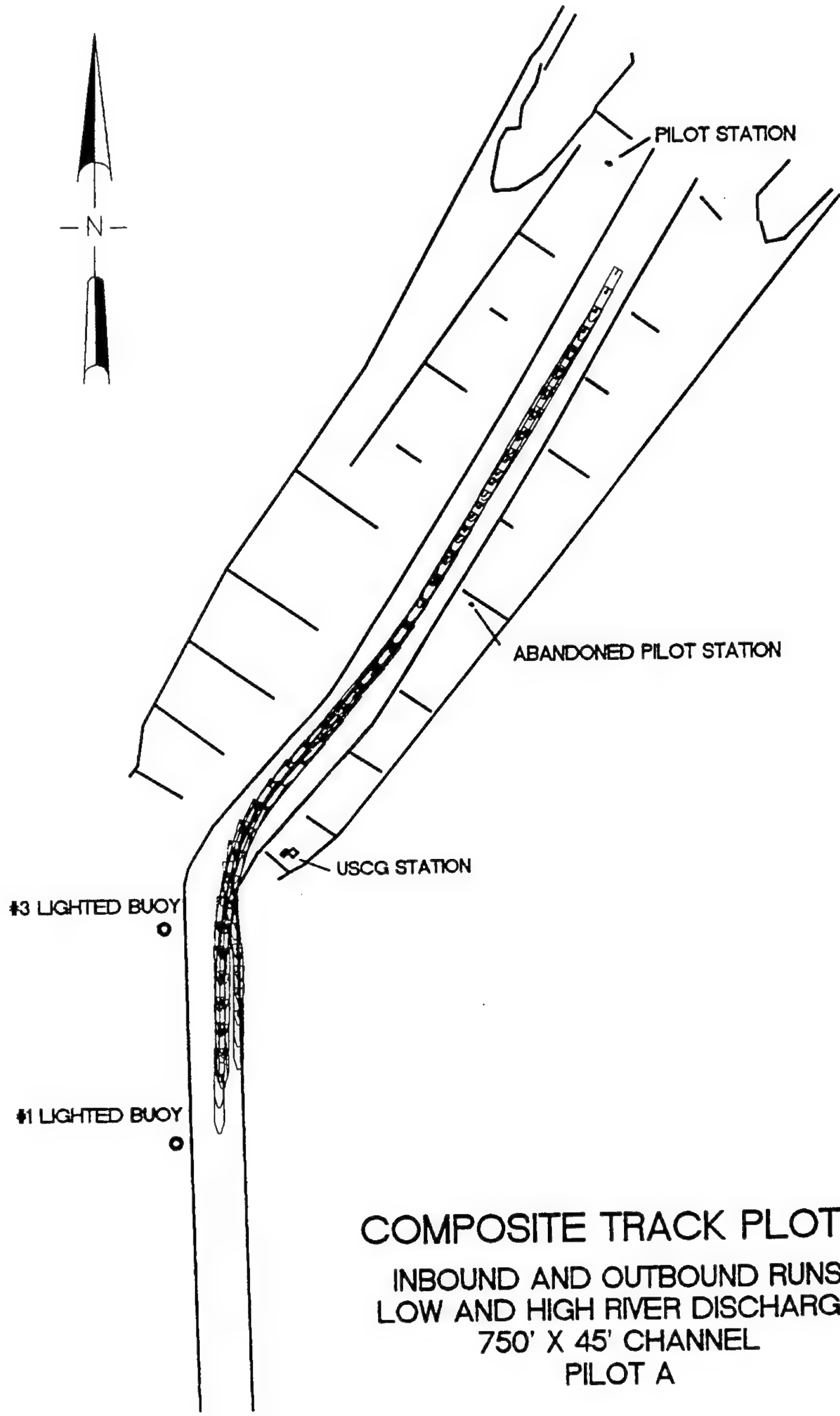


COMPOSITE TRACK PLOTS
INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
675' X 45' CHANNEL
PILOT C

Plate 32



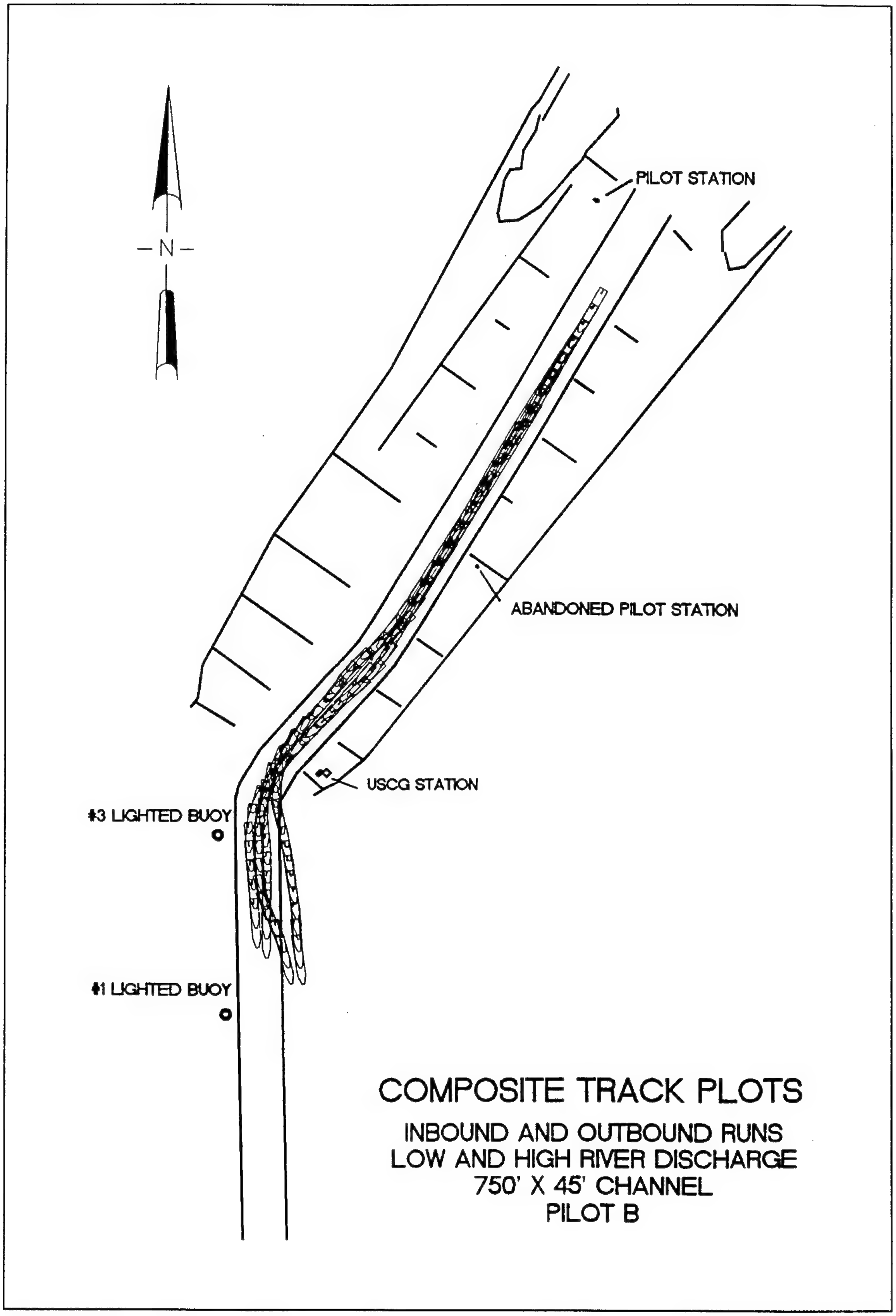
COMPOSITE TRACK PLOTS
INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
675' X 45' CHANNEL
PILOT D



COMPOSITE TRACK PLOTS

INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
750' X 45' CHANNEL
PILOT A

Plate 34



COMPOSITE TRACK PLOTS
INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
750' X 45' CHANNEL
PILOT B

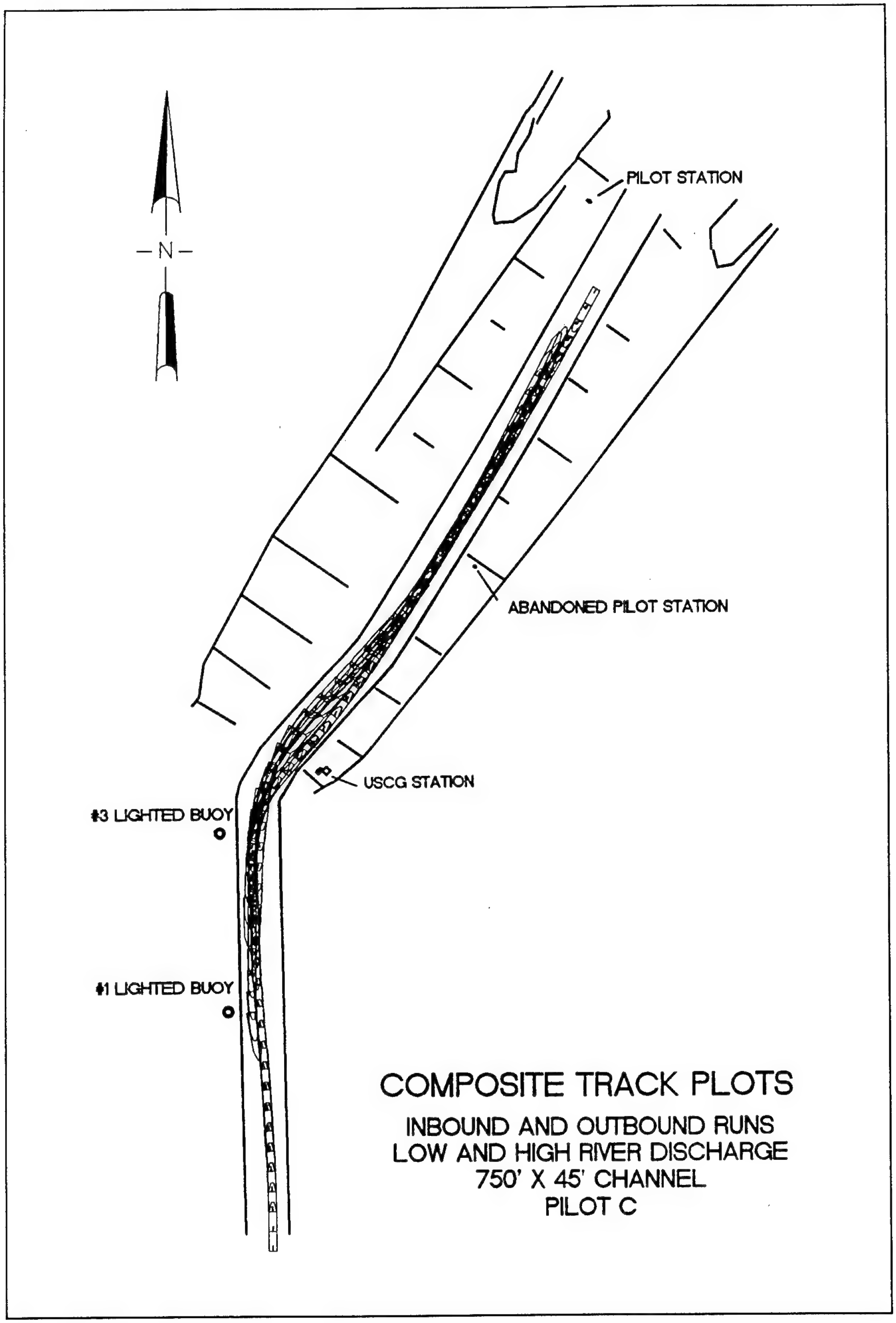
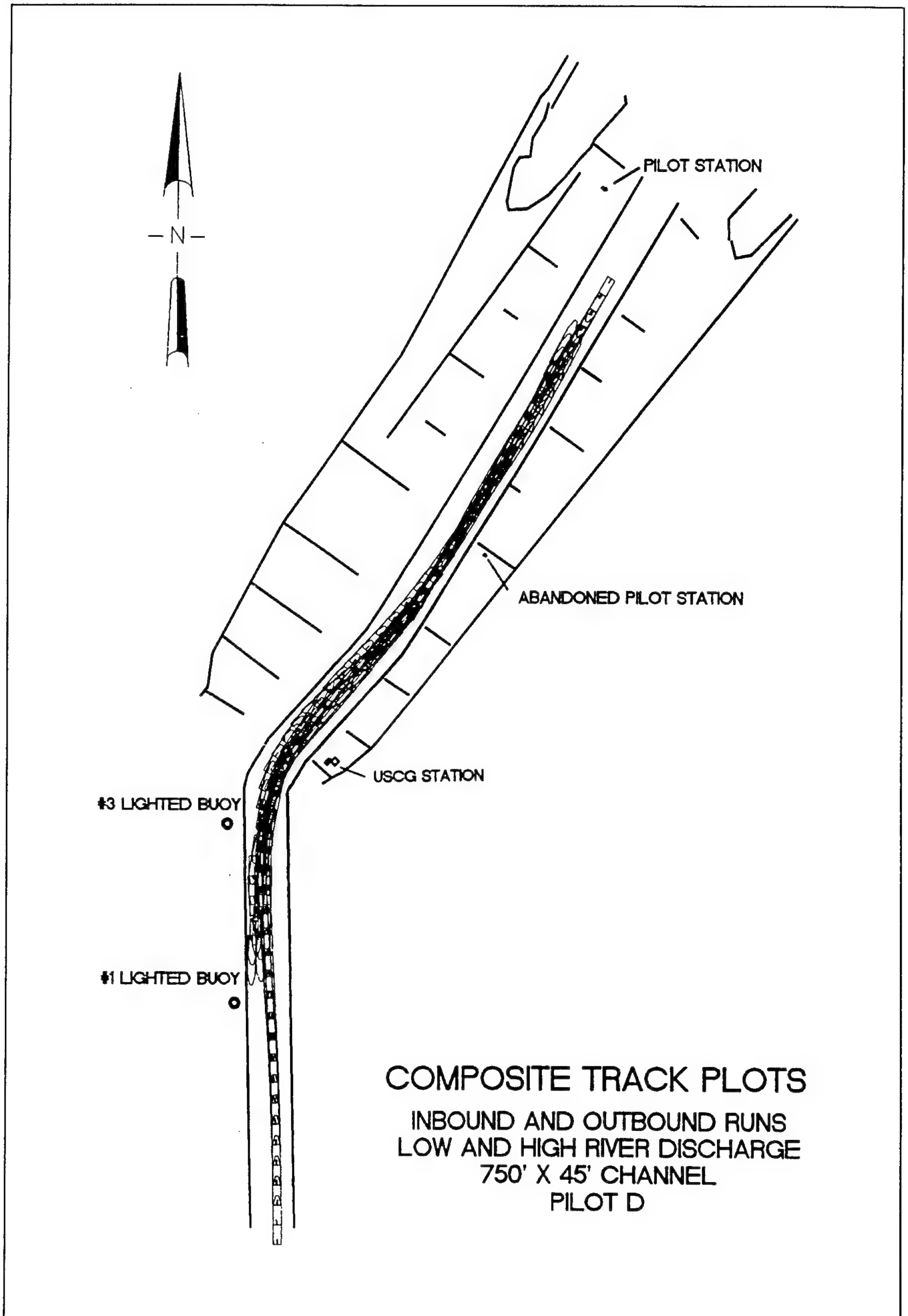
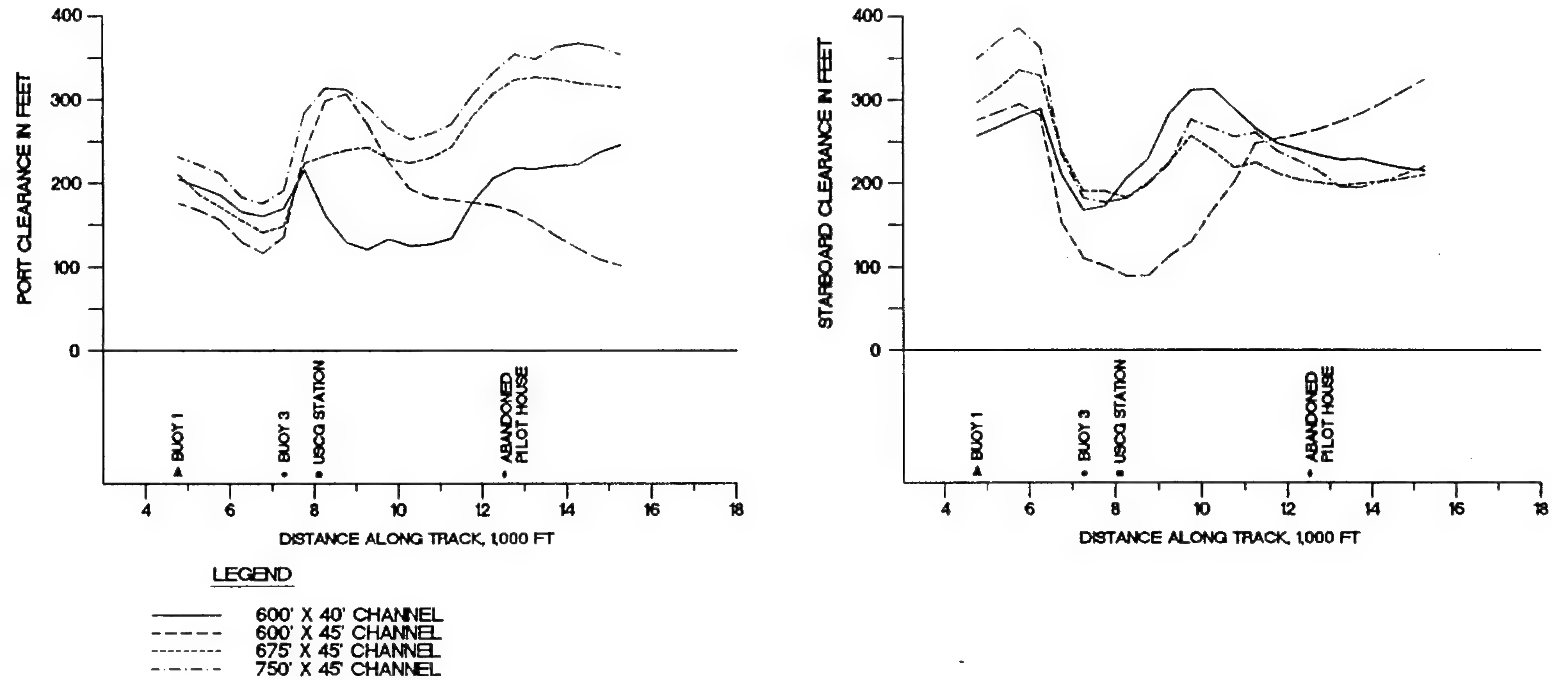
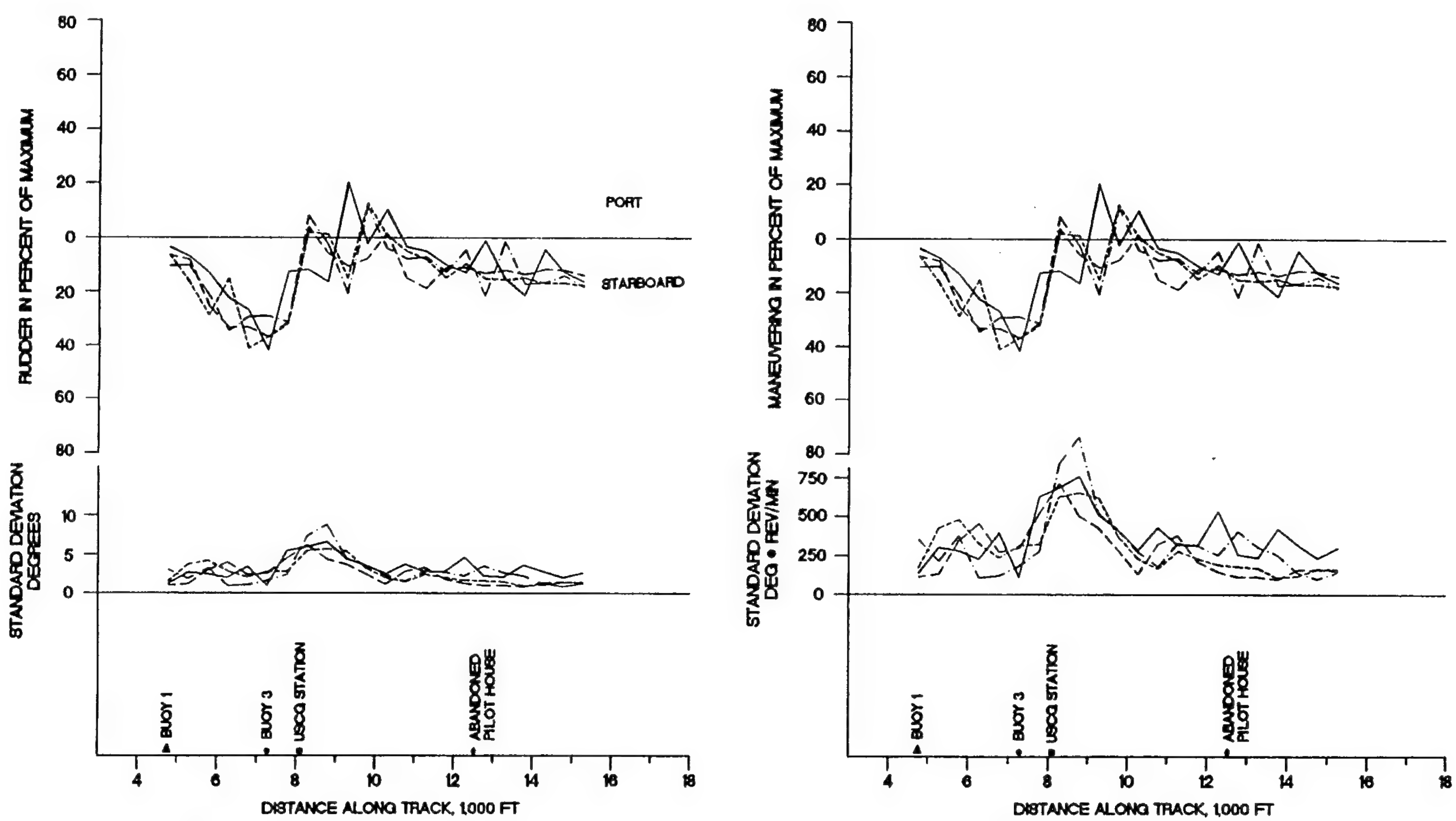

N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
750' X 45' CHANNEL
PILOT C

Plate 36


N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
INBOUND AND OUTBOUND RUNS
LOW AND HIGH RIVER DISCHARGE
750' X 45' CHANNEL
PILOT D



MEAN MINIMUM CHANNEL EDGE CLEARANCE
INBOUND RUNS - LOW RIVER DISCHARGE



LEGEND

- 600' X 40' CHANNEL
- 600' X 45' CHANNEL
- 675' X 45' CHANNEL
- 750' X 45' CHANNEL

MAXIMUM RUDDER IS 48 DEGREES
MAXIMUM ENGINE IS 115 RPM

RUDDER AND MANEUVERING FACTOR PLOTS
INBOUND RUNS - LOW RIVER DISCHARGE

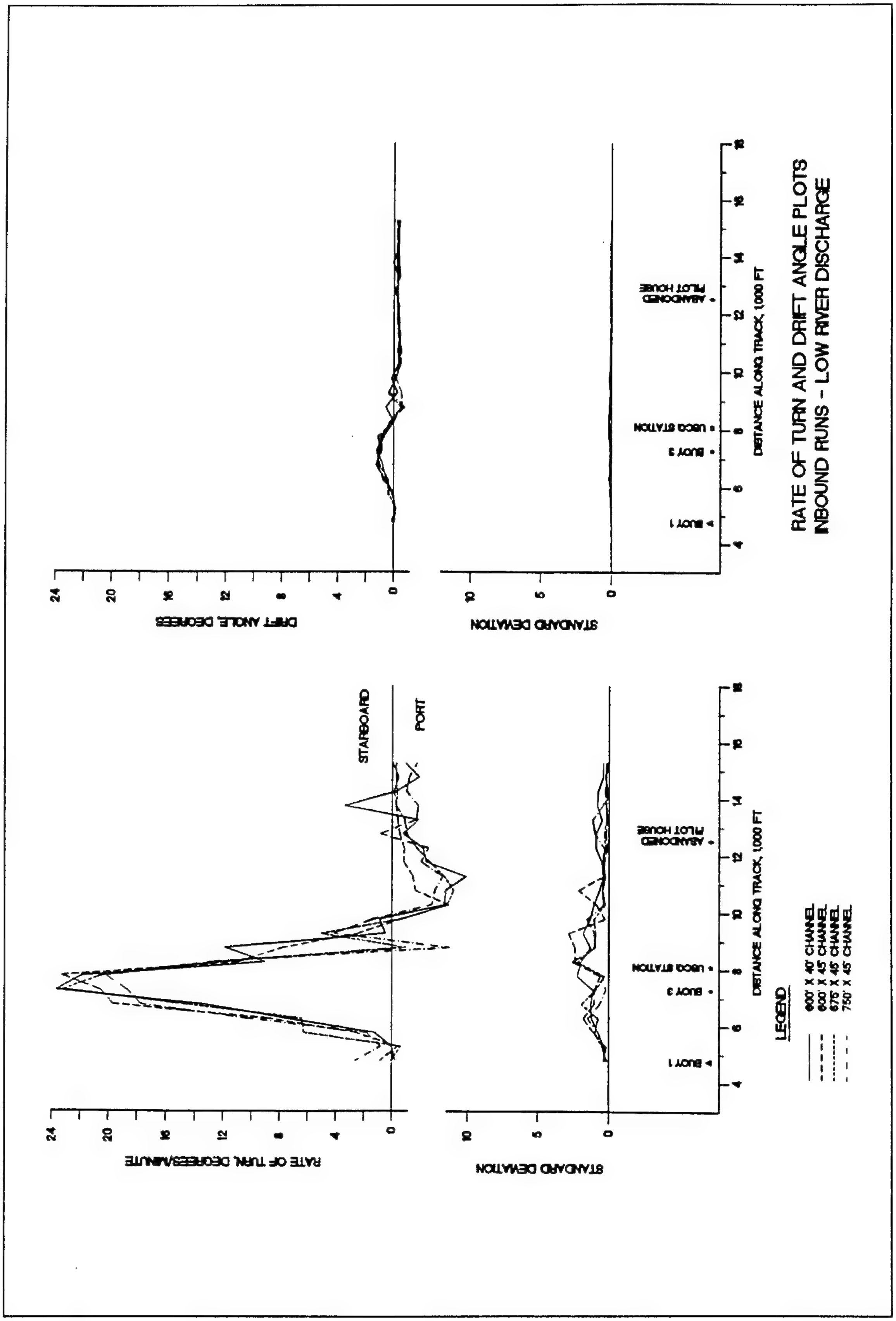
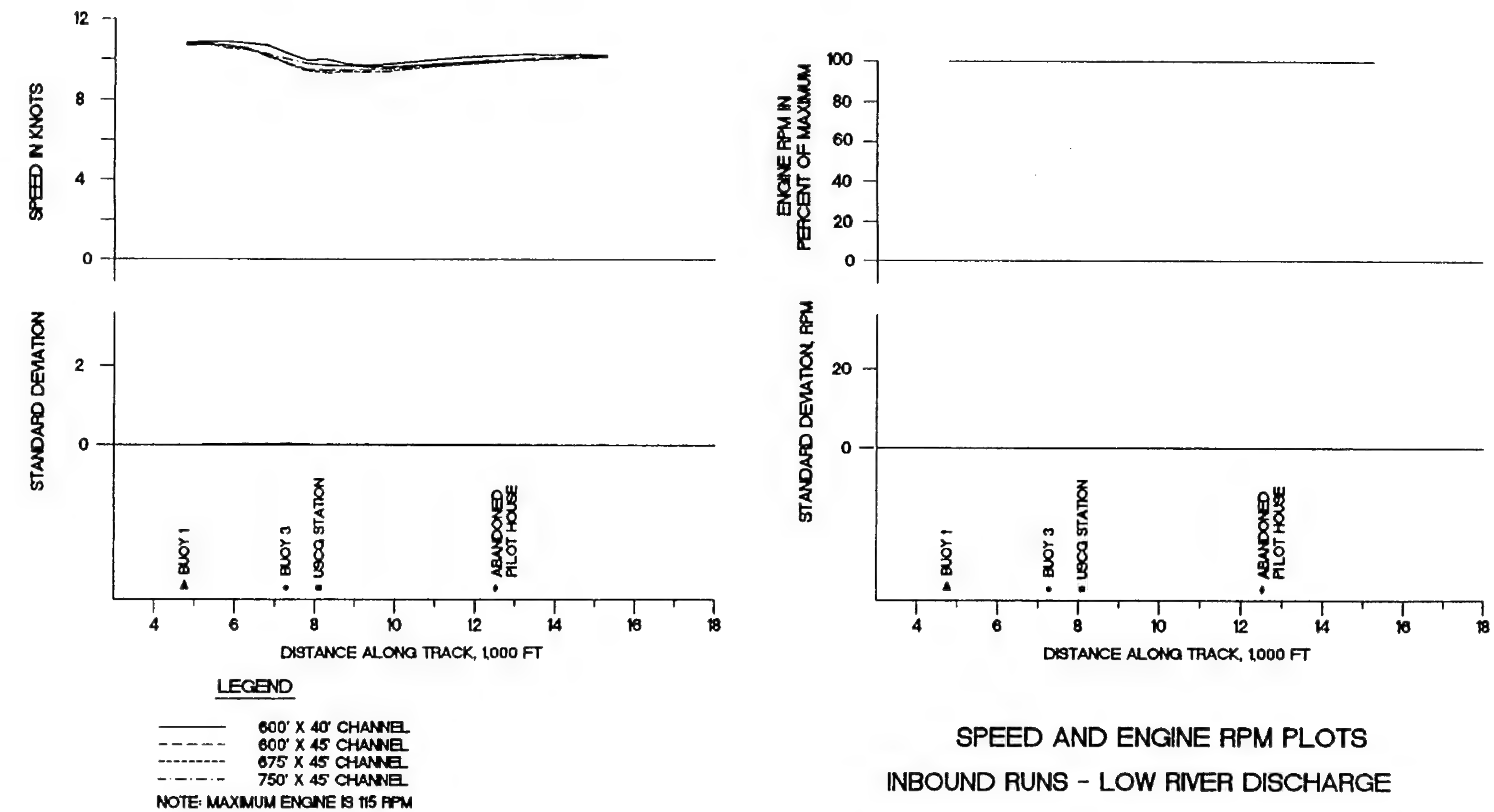
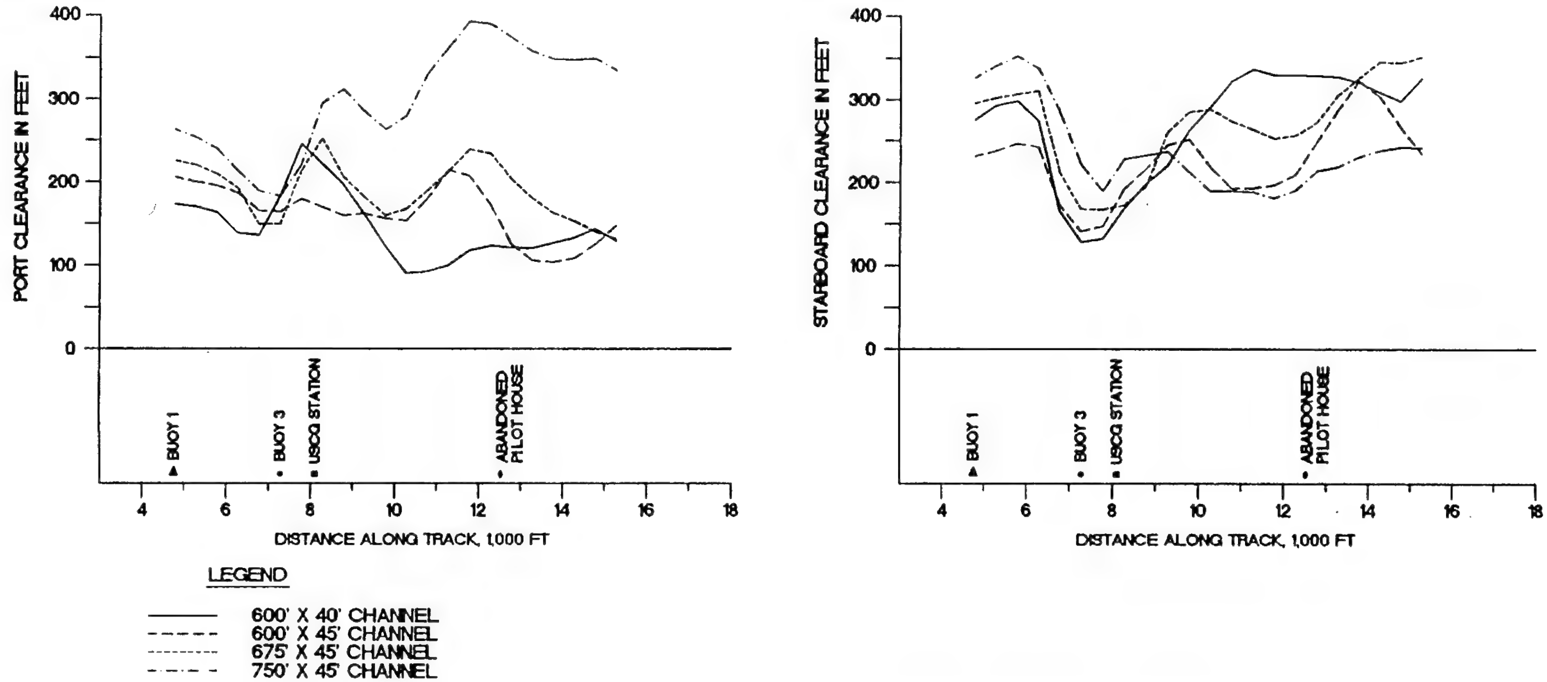

RATE OF TURN AND DRIFT ANGLE PLOTS
INBOUND RUNS - LOW RIVER DISCHARGE
RATE OF TURN, DEGREES/MINUTE
DRIFT ANGLE, DEGREES
STANDARD DEVIATION
STARBOARD
PORT
DISTANCE ALONG TRACK, 1,000 FT
BUOY 1
BUOY 3
USCG STATION
ABANDONED PILOT HOUSE
LEGEND
600' X 40' CHANNEL
600' X 45' CHANNEL
675' X 45' CHANNEL
750' X 45' CHANNEL

Plate 40

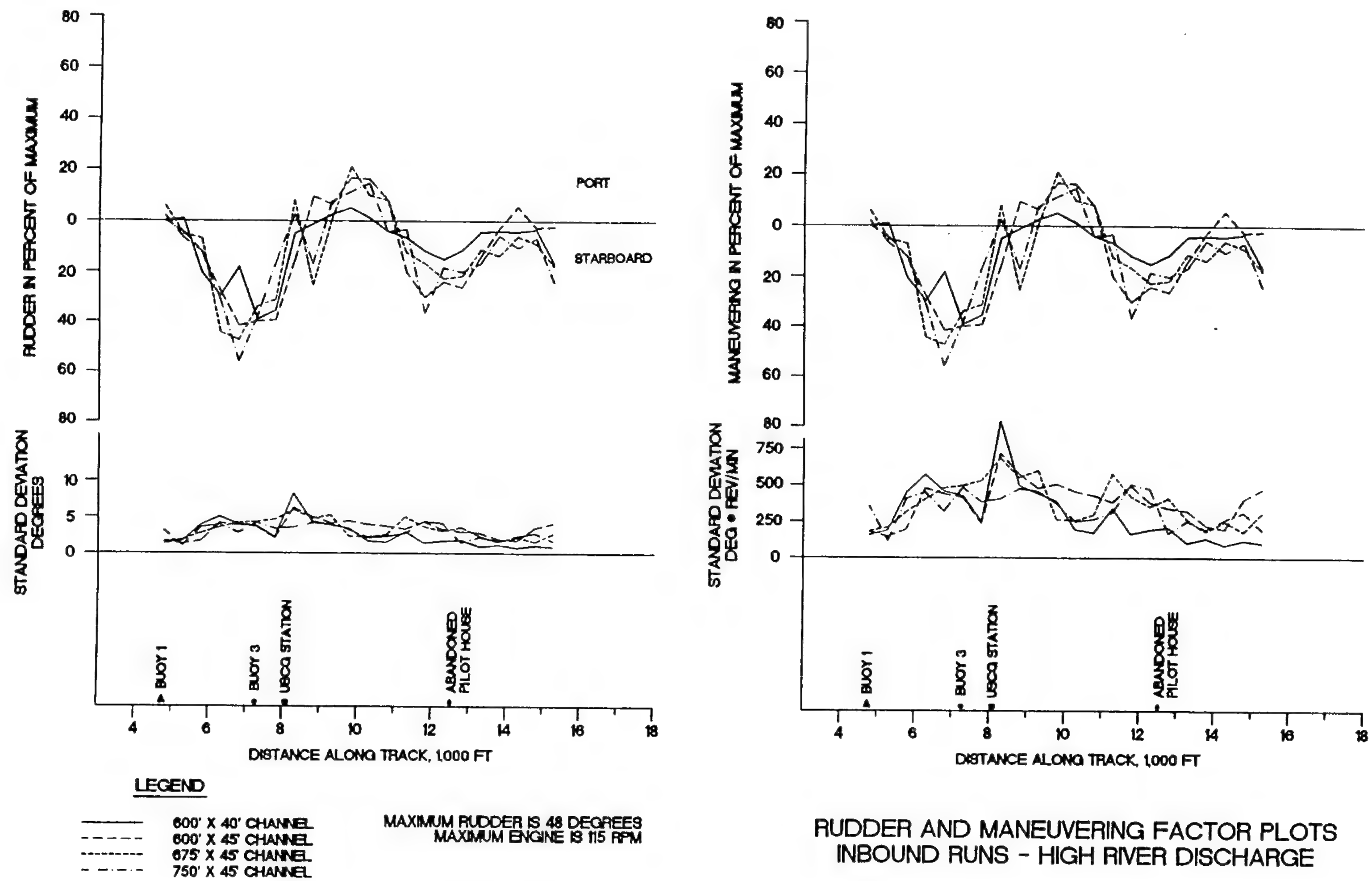


SPEED AND ENGINE RPM PLOTS

INBOUND RUNS - LOW RIVER DISCHARGE



MEAN MINIMUM CHANNEL EDGE CLEARANCE
INBOUND RUNS - HIGH RIVER DISCHARGE



RUDDER AND MANEUVERING FACTOR PLOTS
INBOUND RUNS - HIGH RIVER DISCHARGE

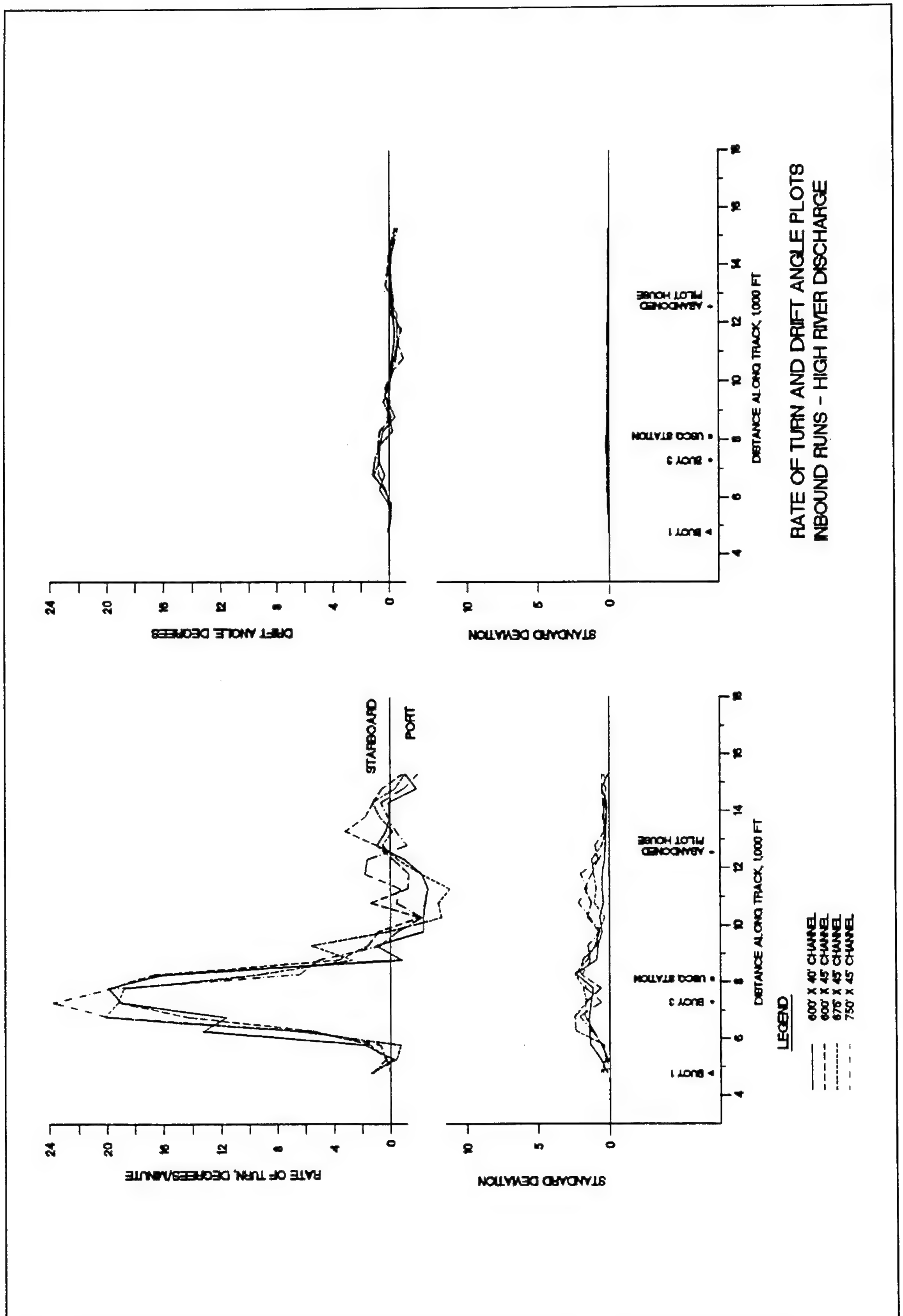
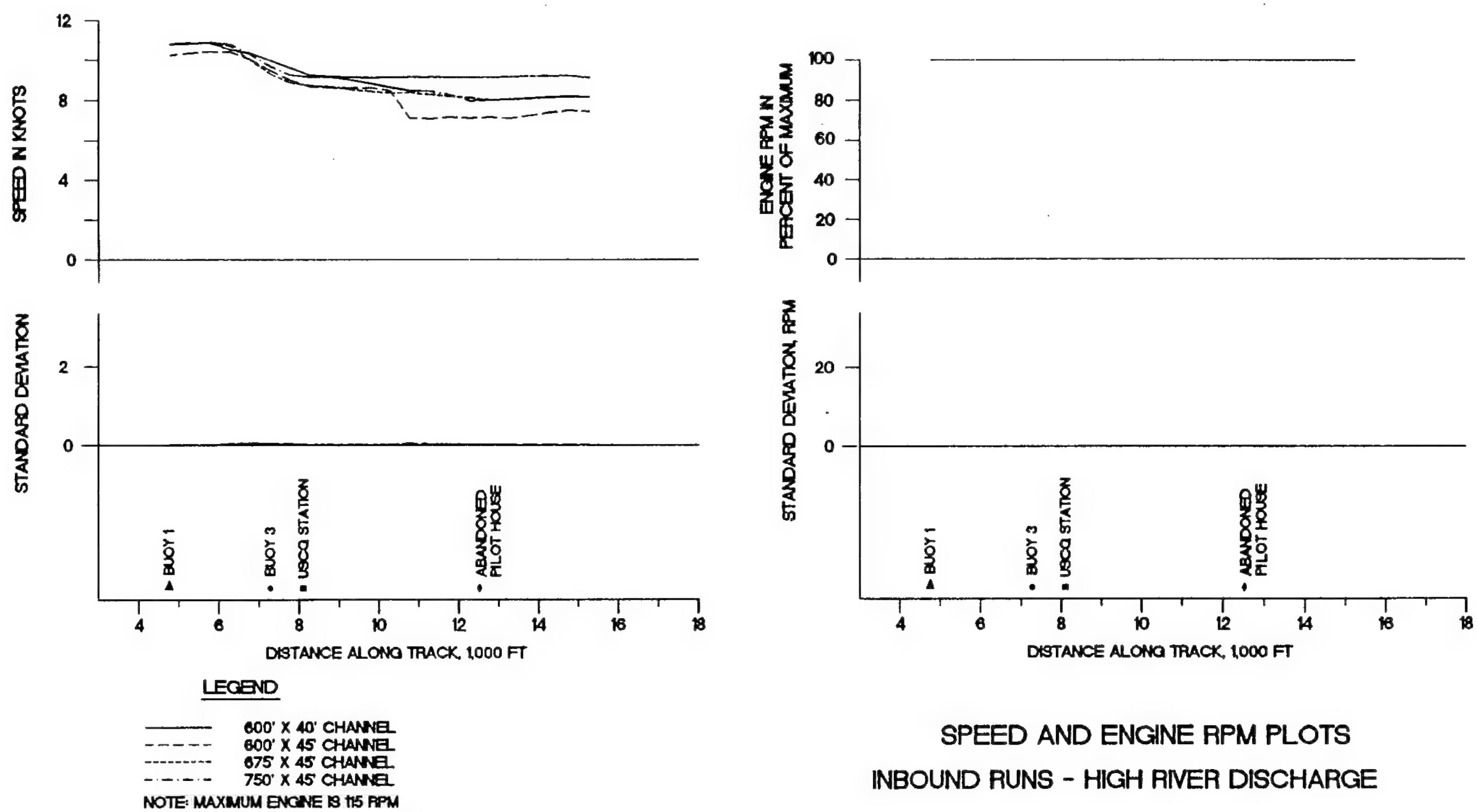
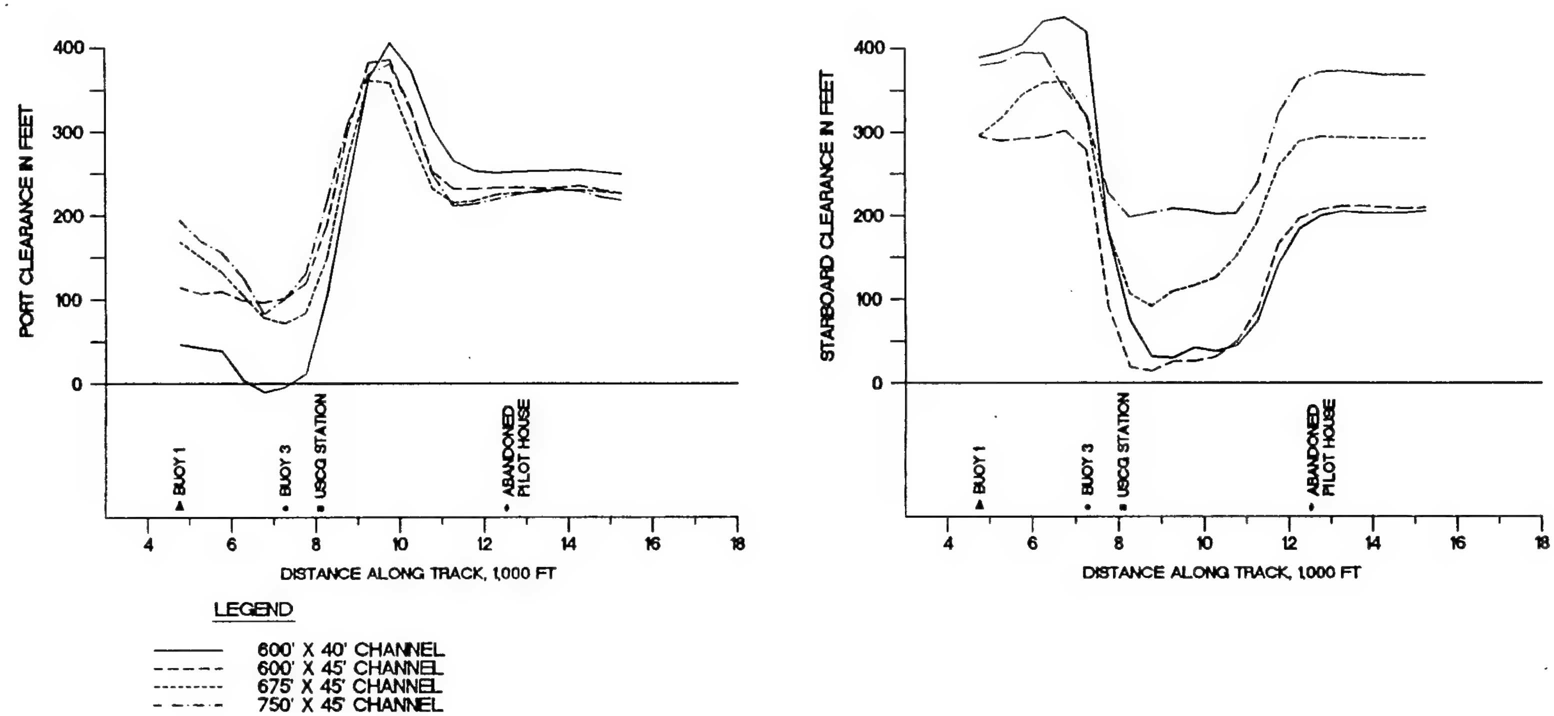

RATE OF TURN AND DRIFT ANGLE PLOTS
INBOUND RUNS - HIGH RIVER DISCHARGE
DRIFT ANGLE, DEGREES
RATE OF TURN, DEGREES/MINUTE
STANDARD DEVIATION
DISTANCE ALONG TRACK, 1,000 FT
BUOY 1
BUOY 3
USCG STATION
ABANDONED PILOT HOUSE
STARBOARD
PORT
LEGEND
600' X 40' CHANNEL
600' X 45' CHANNEL
675' X 45' CHANNEL
750' X 45' CHANNEL

Plate 44

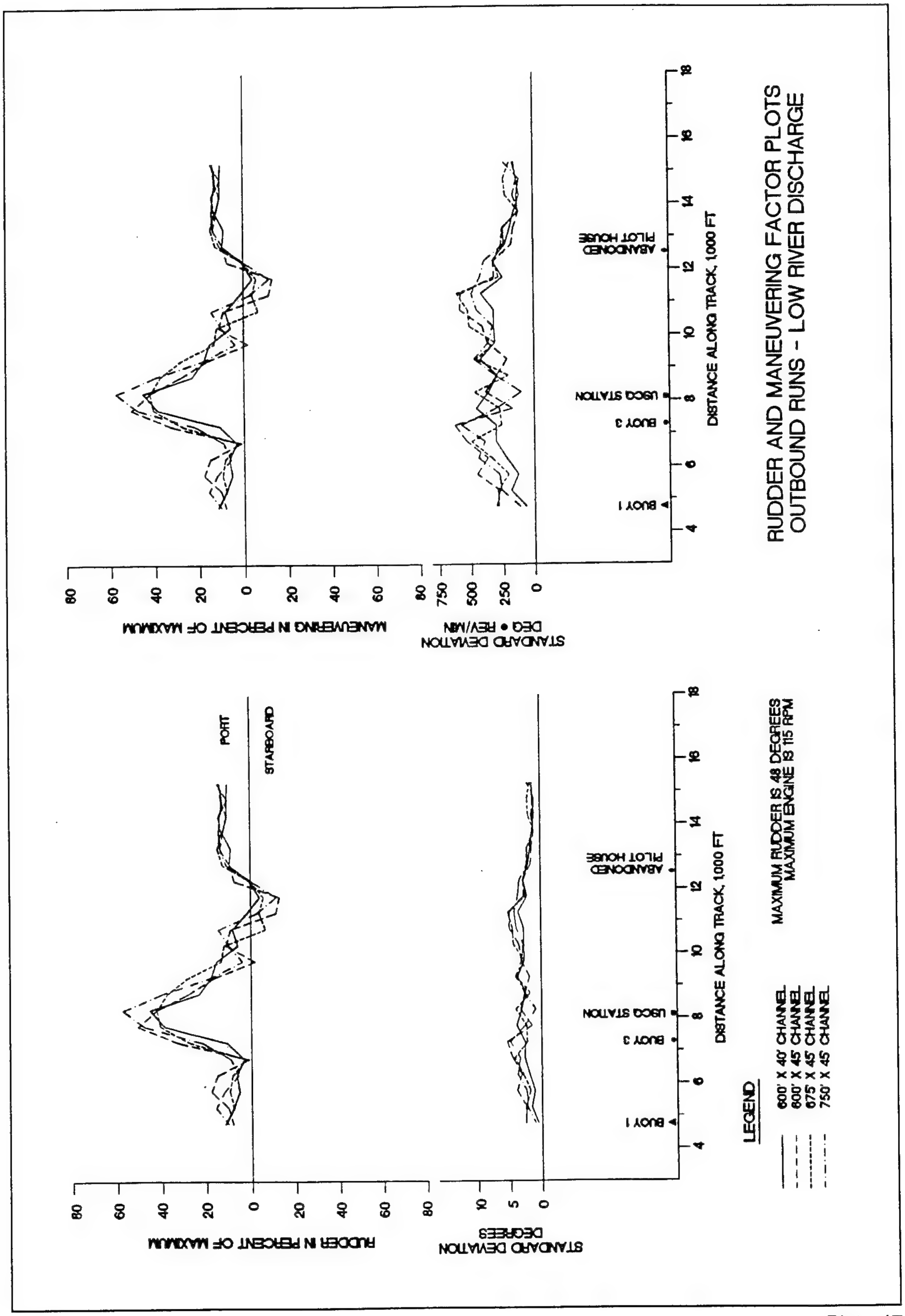


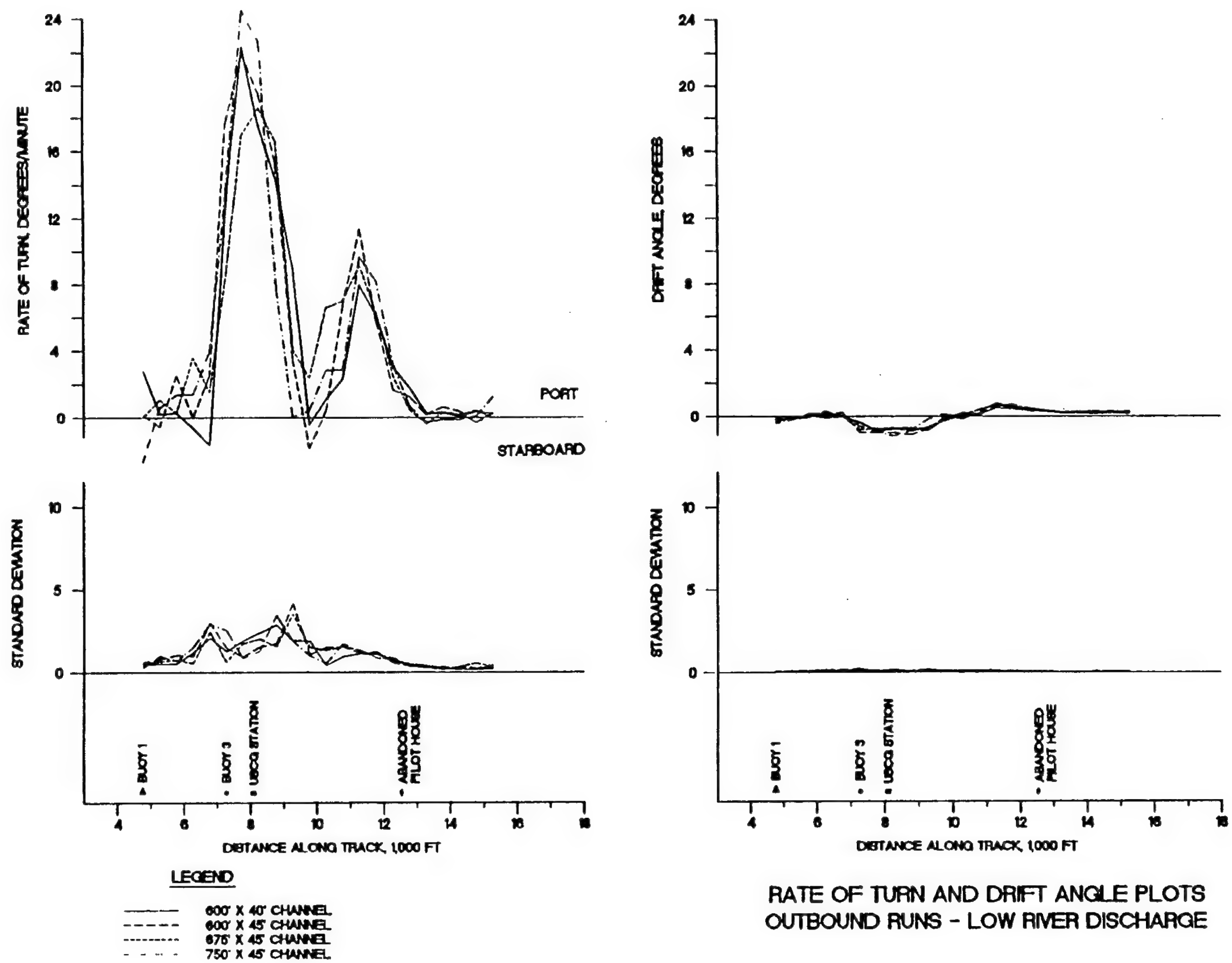
SPEED AND ENGINE RPM PLOTS

INBOUND RUNS - HIGH RIVER DISCHARGE

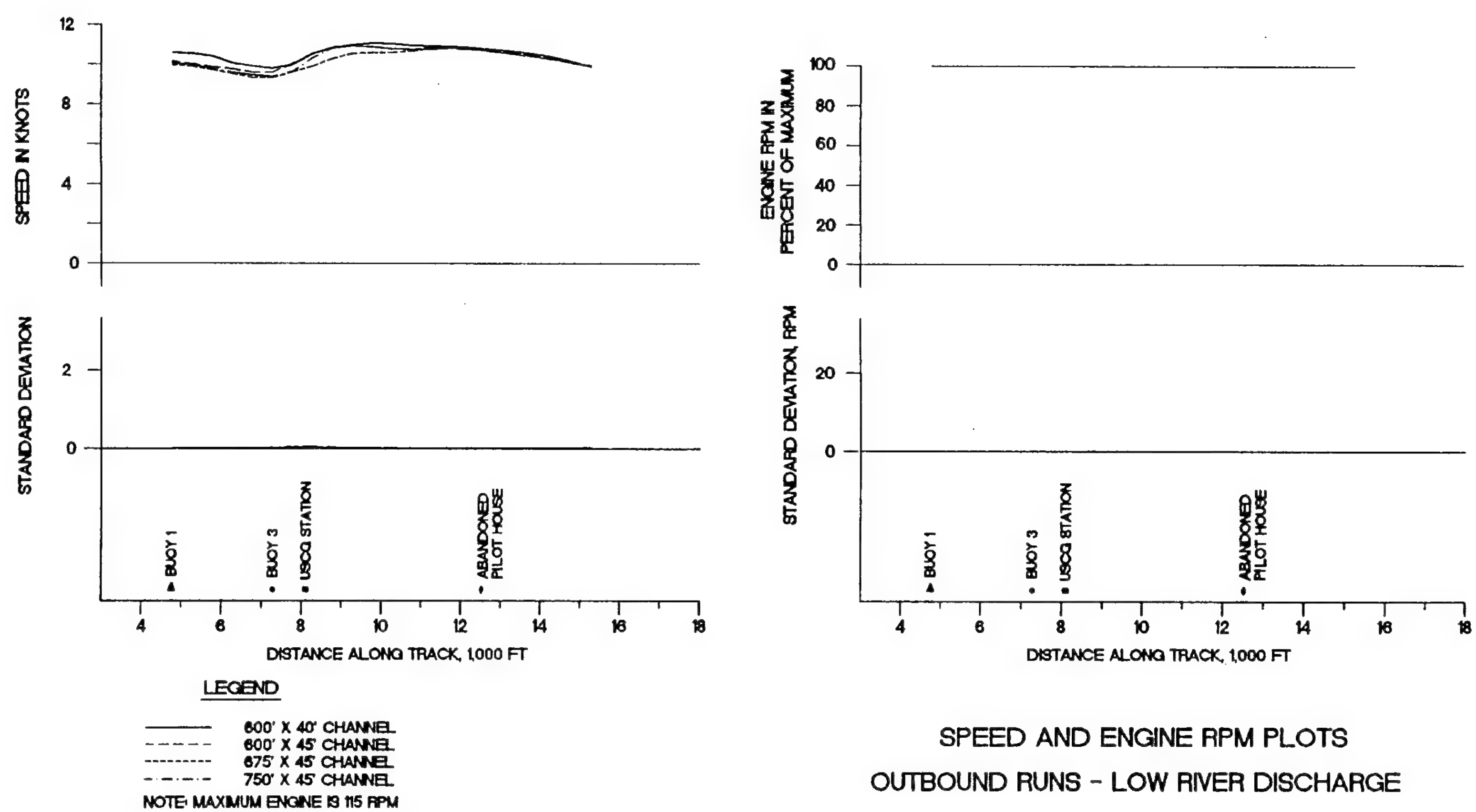


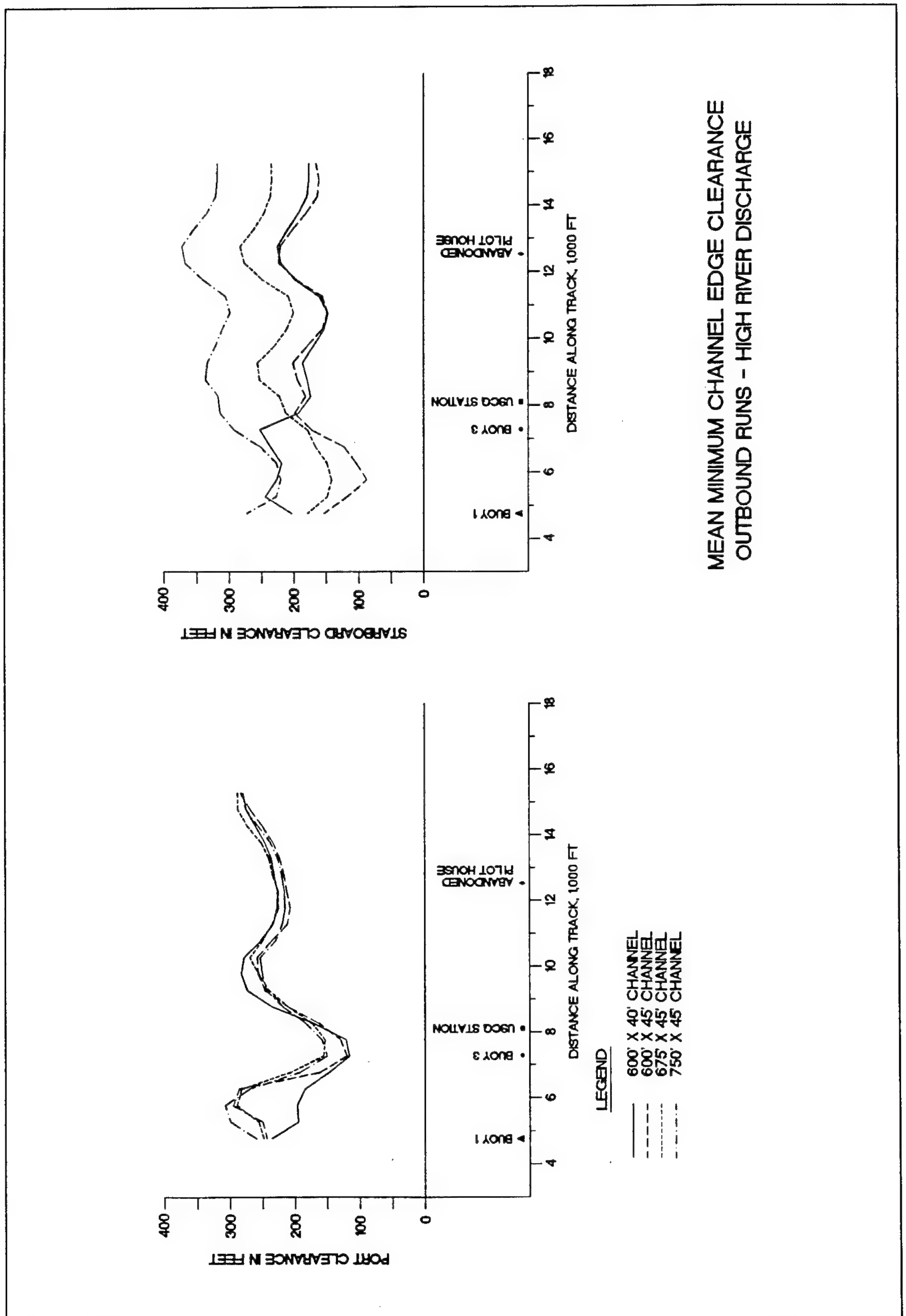
MEAN MINIMUM CHANNEL EDGE CLEARANCE
OUTBOUND RUNS - LOW RIVER DISCHARGE


RUDDER AND MANEUVERING FACTOR PLOTS
OUTBOUND RUNS - LOW RIVER DISCHARGE
RUDDER IN PERCENT OF MAXIMUM
PORT
STARBOARD
STANDARD DEVIATION DEGREES
MANEUVERING IN PERCENT OF MAXIMUM
STANDARD DEVIATION DEG • REV/MIN
DISTANCE ALONG TRACK, 1000 FT
BUOY 1
BUOY 3
USCG STATION
ABANDONED PILOT HOUSE
LEGEND
600' X 40' CHANNEL
600' X 45' CHANNEL
675' X 45' CHANNEL
750' X 45' CHANNEL
MAXIMUM RUDDER IS 48 DEGREES
MAXIMUM ENGINE IS 115 RPM

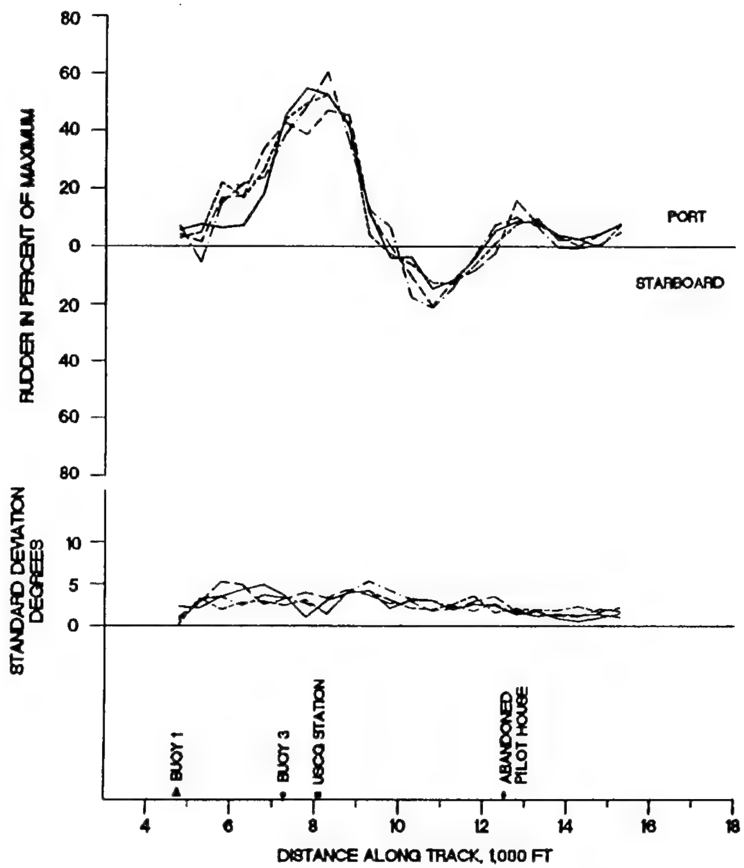


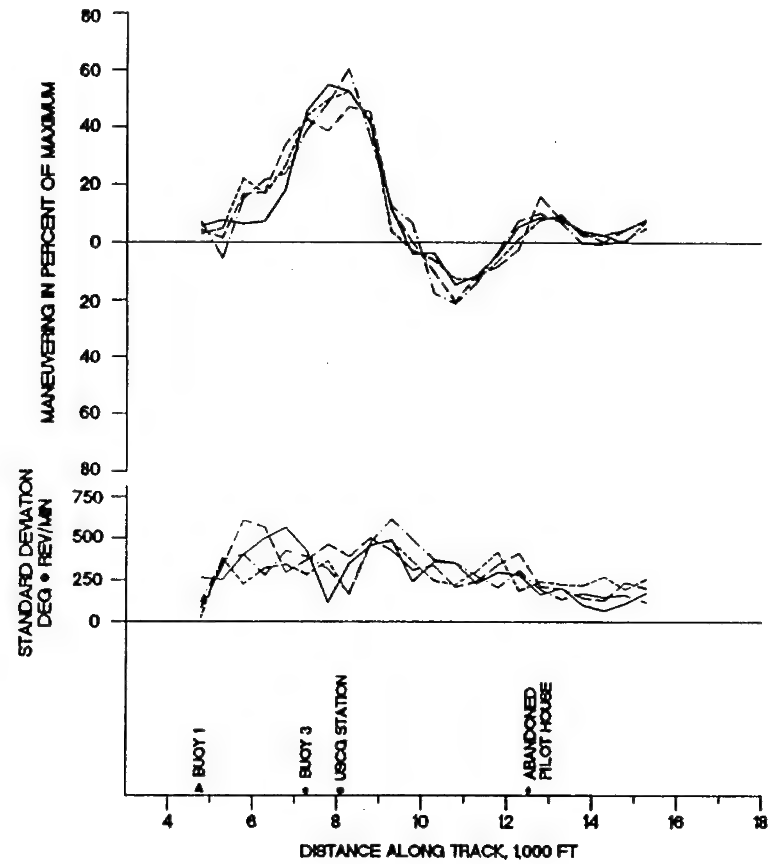
RATE OF TURN AND DRIFT ANGLE PLOTS
OUTBOUND RUNS - LOW RIVER DISCHARGE


SPEED IN KNOTS
STANDARD DEVIATION
ENGINE RPM IN PERCENT OF MAXIMUM
STANDARD DEVIATION, RPM
BUOY 1
BUOY 3
USCG STATION
ABANDONED PILOT HOUSE
DISTANCE ALONG TRACK, 1,000 FT
LEGEND
600' X 40' CHANNEL
600' X 45' CHANNEL
675' X 45' CHANNEL
750' X 45' CHANNEL
NOTE: MAXIMUM ENGINE IS 115 RPM
SPEED AND ENGINE RPM PLOTS
OUTBOUND RUNS - LOW RIVER DISCHARGE



MEAN MINIMUM CHANNEL EDGE CLEARANCE
OUTBOUND RUNS - HIGH RIVER DISCHARGE
PORT CLEARANCE IN FEET
STARBOARD CLEARANCE IN FEET
DISTANCE ALONG TRACK, 1,000 FT
BUOY 1
BUOY 3
USCG STATION
ABANDONED PILOT HOUSE
LEGEND
600' X 40' CHANNEL
600' X 45' CHANNEL
675' X 45' CHANNEL
750' X 45' CHANNEL





LEGEND

- 600' X 40' CHANNEL
- 600' X 45' CHANNEL
- 675' X 45' CHANNEL
- 750' X 45' CHANNEL

MAXIMUM RUDDER IS 48 DEGREES
MAXIMUM ENGINE IS 115 RPM

RUDDER AND MANEUVERING FACTOR PLOTS
OUTBOUND RUNS - HIGH RIVER DISCHARGE

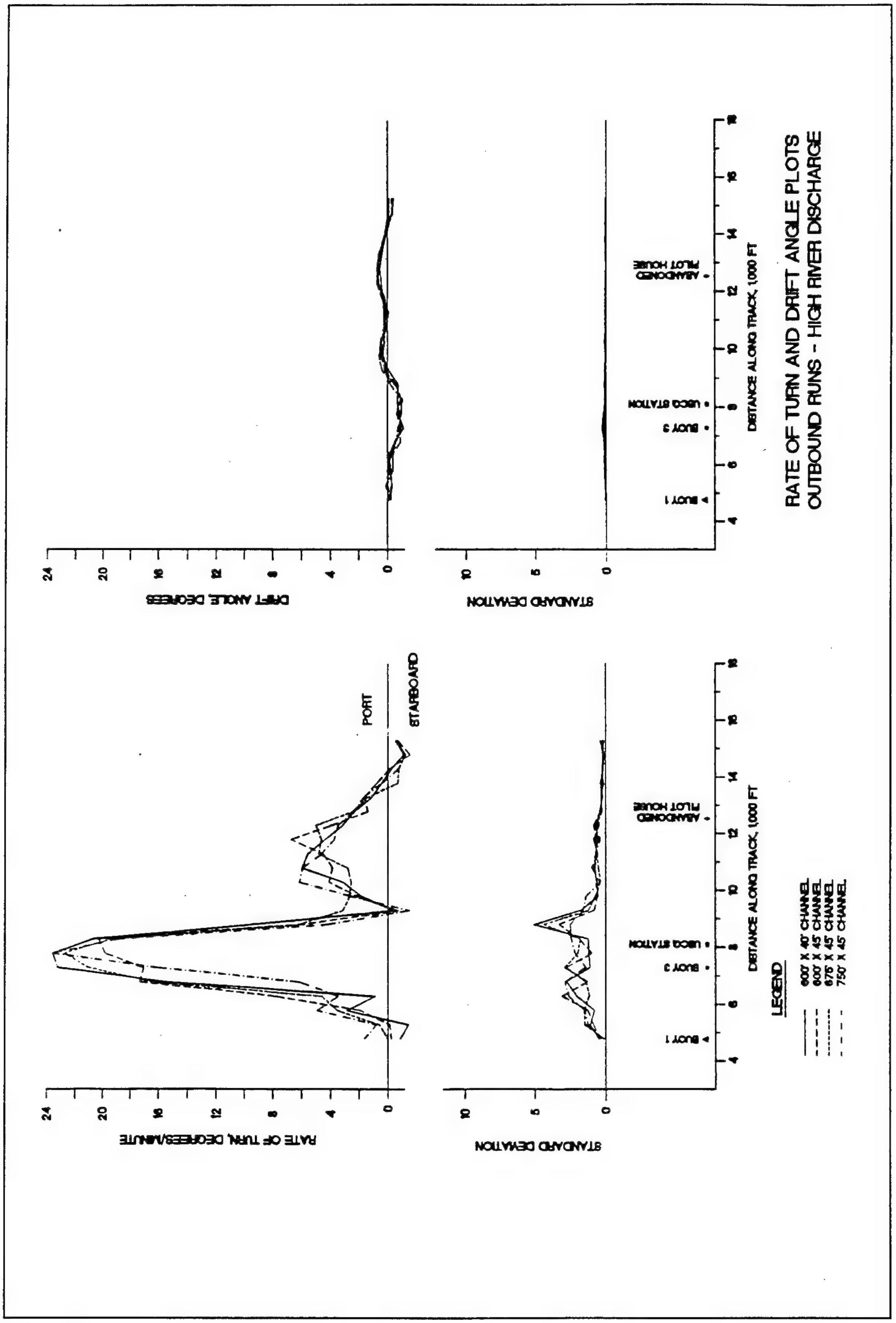
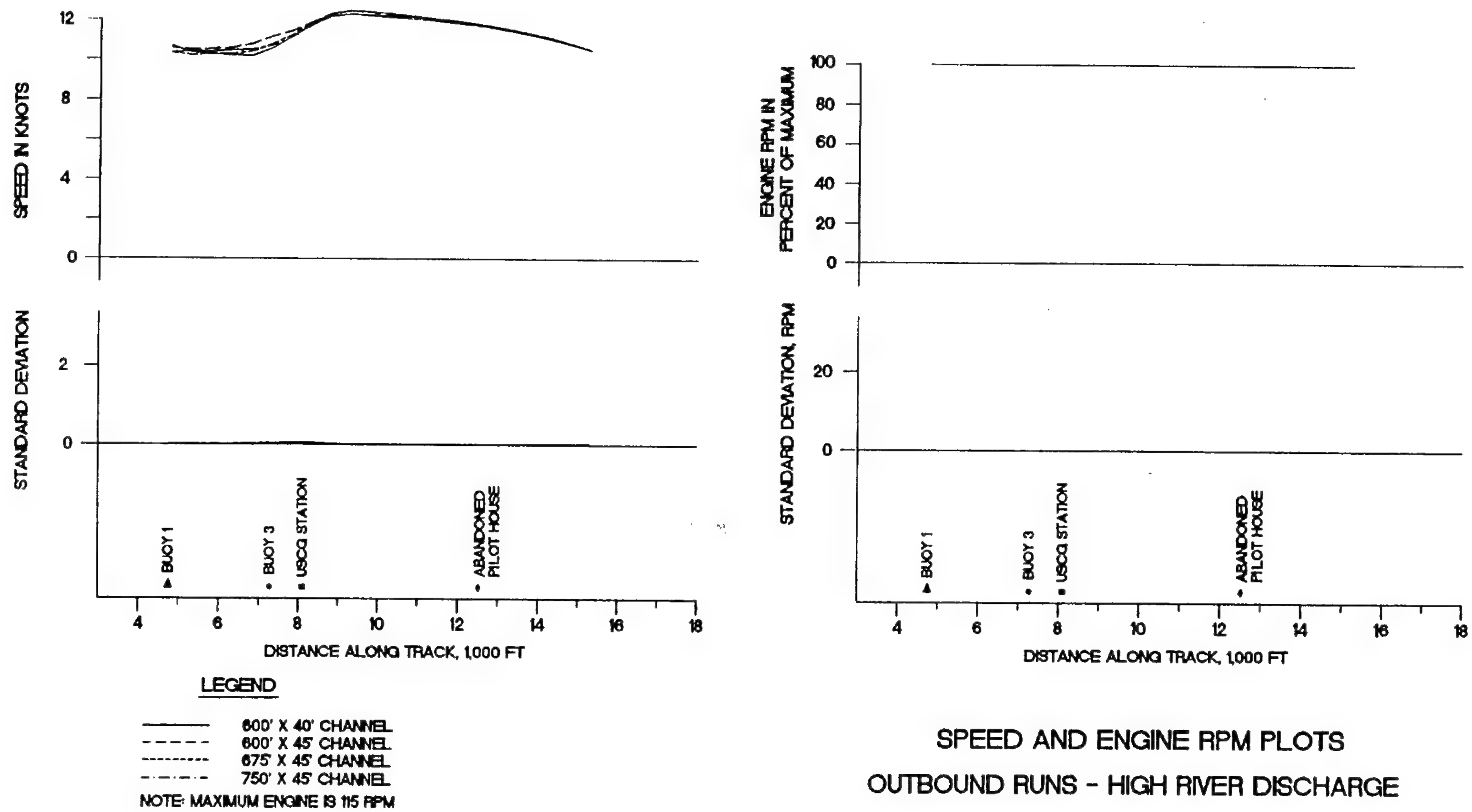
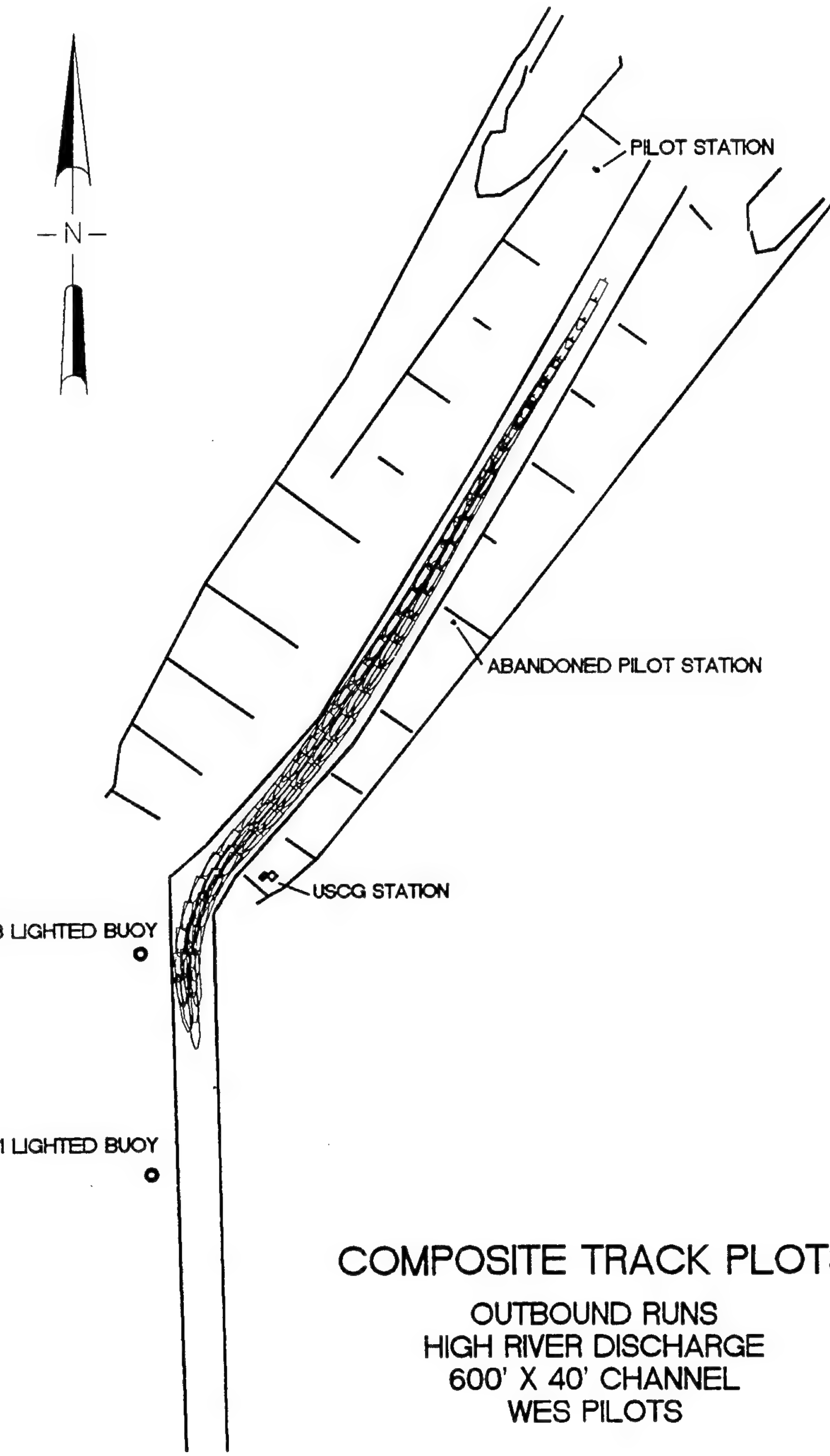

RATE OF TURN AND DRIFT ANGLE PLOTS
OUTBOUND RUNS - HIGH RIVER DISCHARGE
RATE OF TURN, DEGREES/MINUTE
DRIFT ANGLE, DEGREES
STANDARD DEVIATION
PORT
STARBOARD
DISTANCE ALONG TRACK, 1,000 FT
BUOY 1
BUOY 3
USCG STATION
ABANDONED PILOT HOUSE
LEGEND
600' X 40' CHANNEL
600' X 45' CHANNEL
675' X 45' CHANNEL
750' X 45' CHANNEL

Plate 52



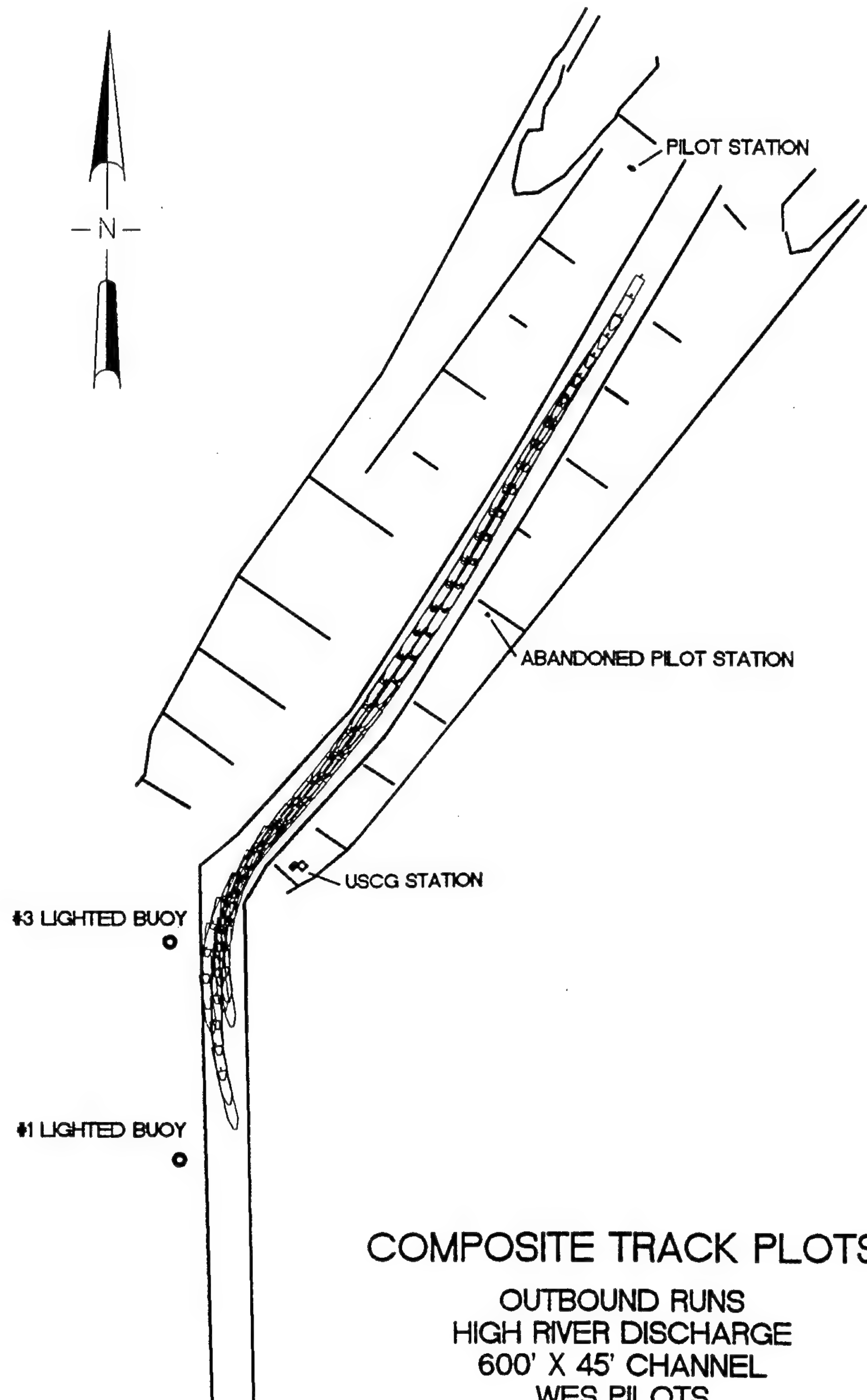
SPEED AND ENGINE RPM PLOTS

OUTBOUND RUNS - HIGH RIVER DISCHARGE



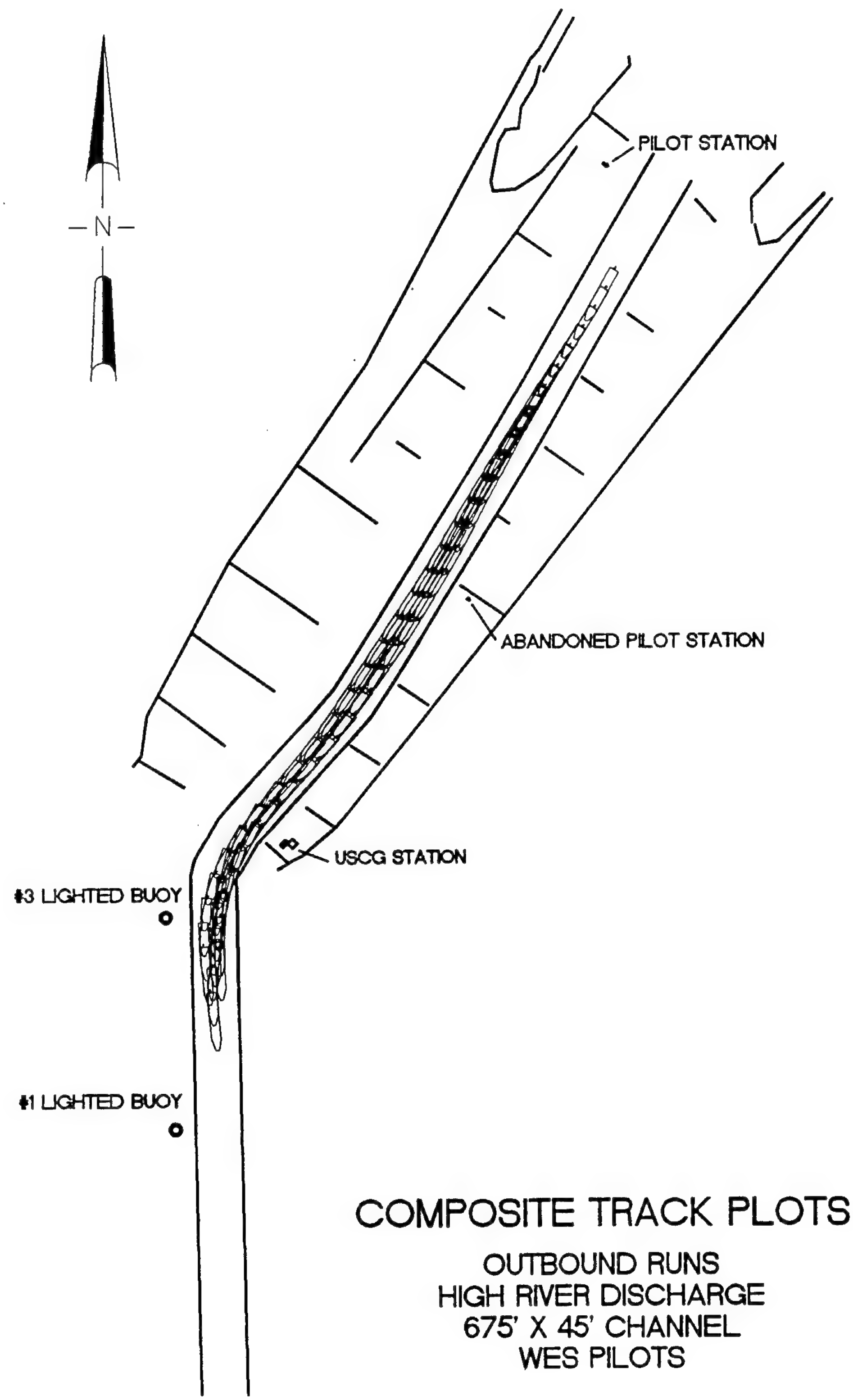
COMPOSITE TRACK PLOTS

OUTBOUND RUNS
HIGH RIVER DISCHARGE
600' X 40' CHANNEL
WES PILOTS



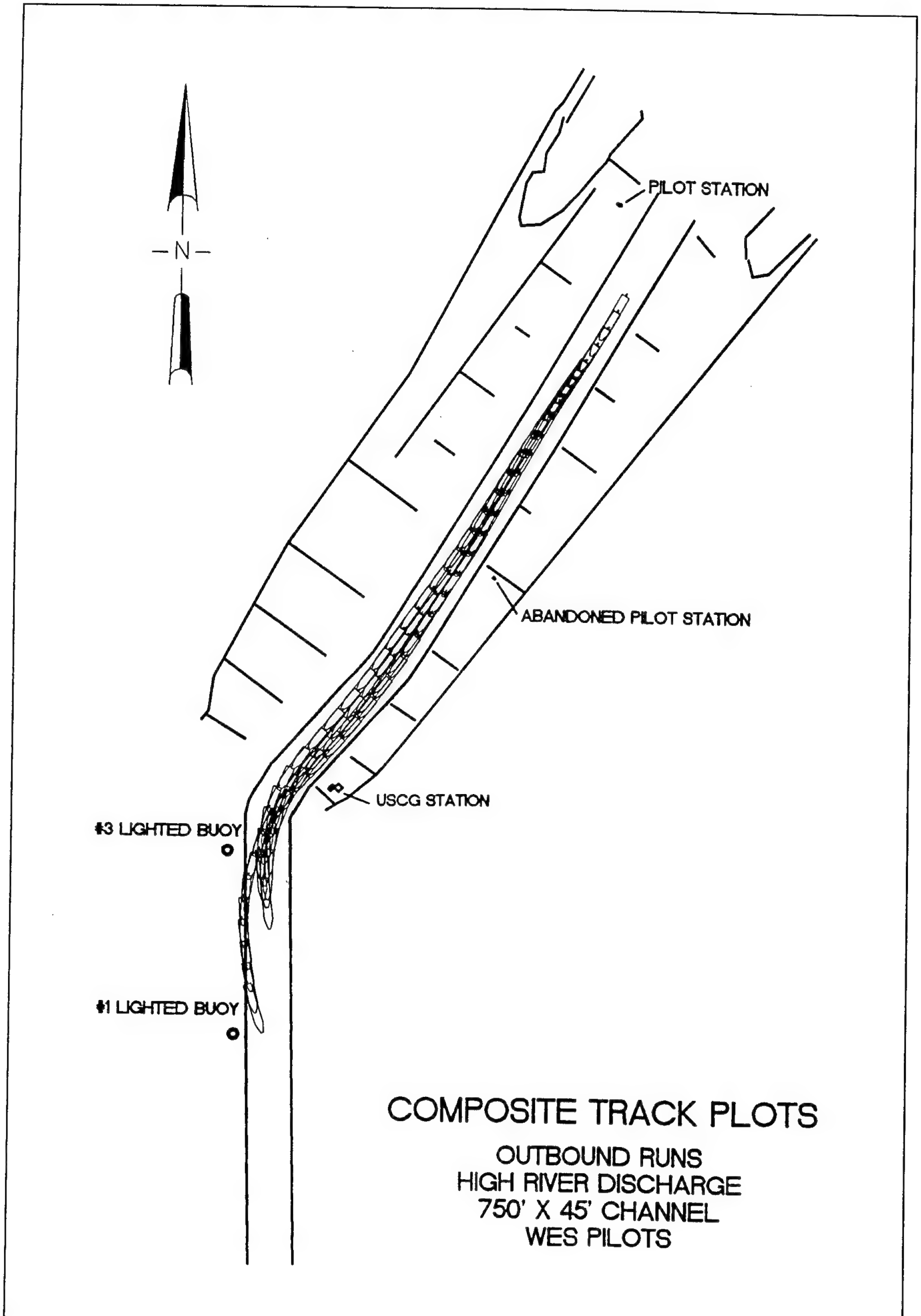
COMPOSITE TRACK PLOTS

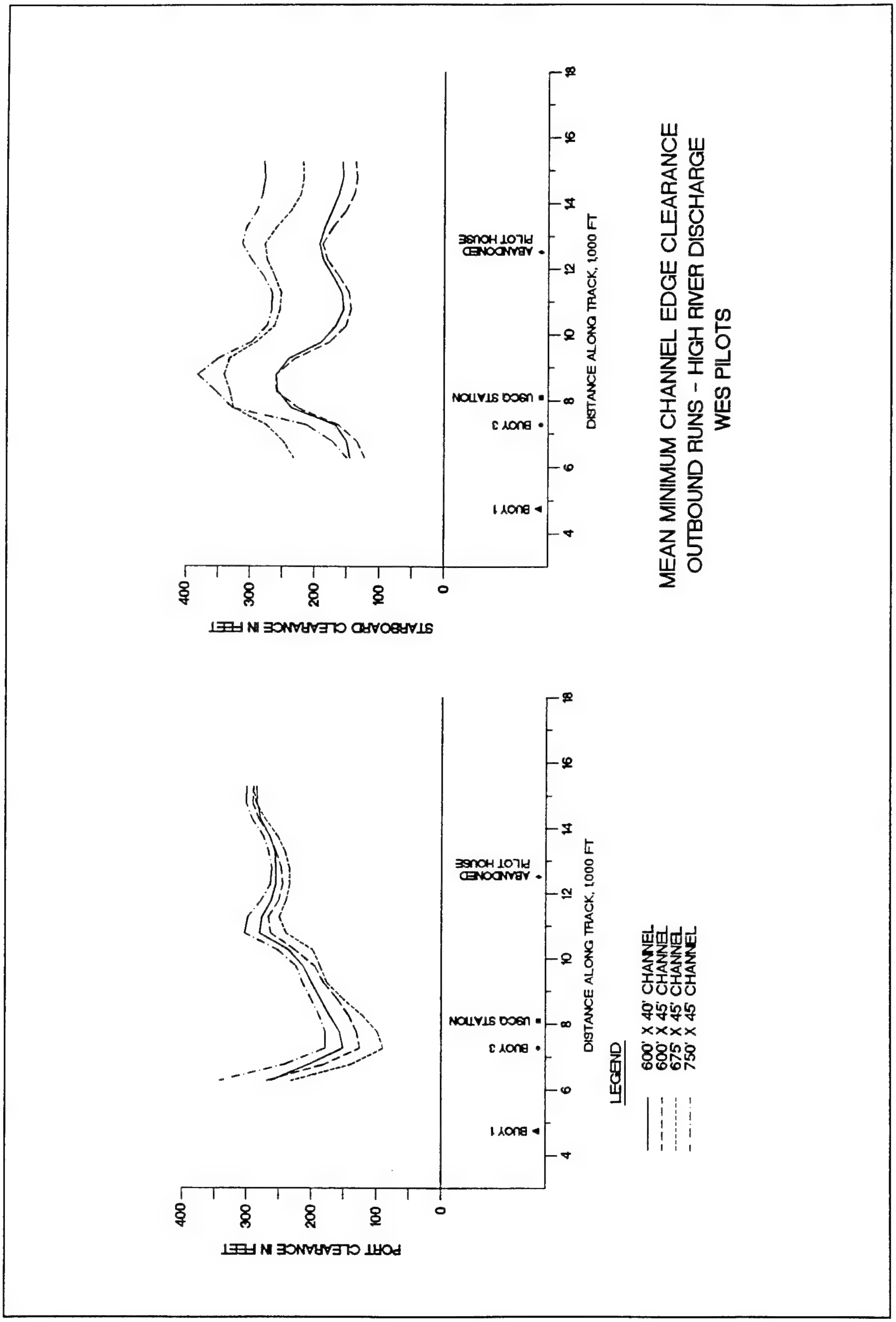
OUTBOUND RUNS
HIGH RIVER DISCHARGE
600' X 45' CHANNEL
WES PILOTS

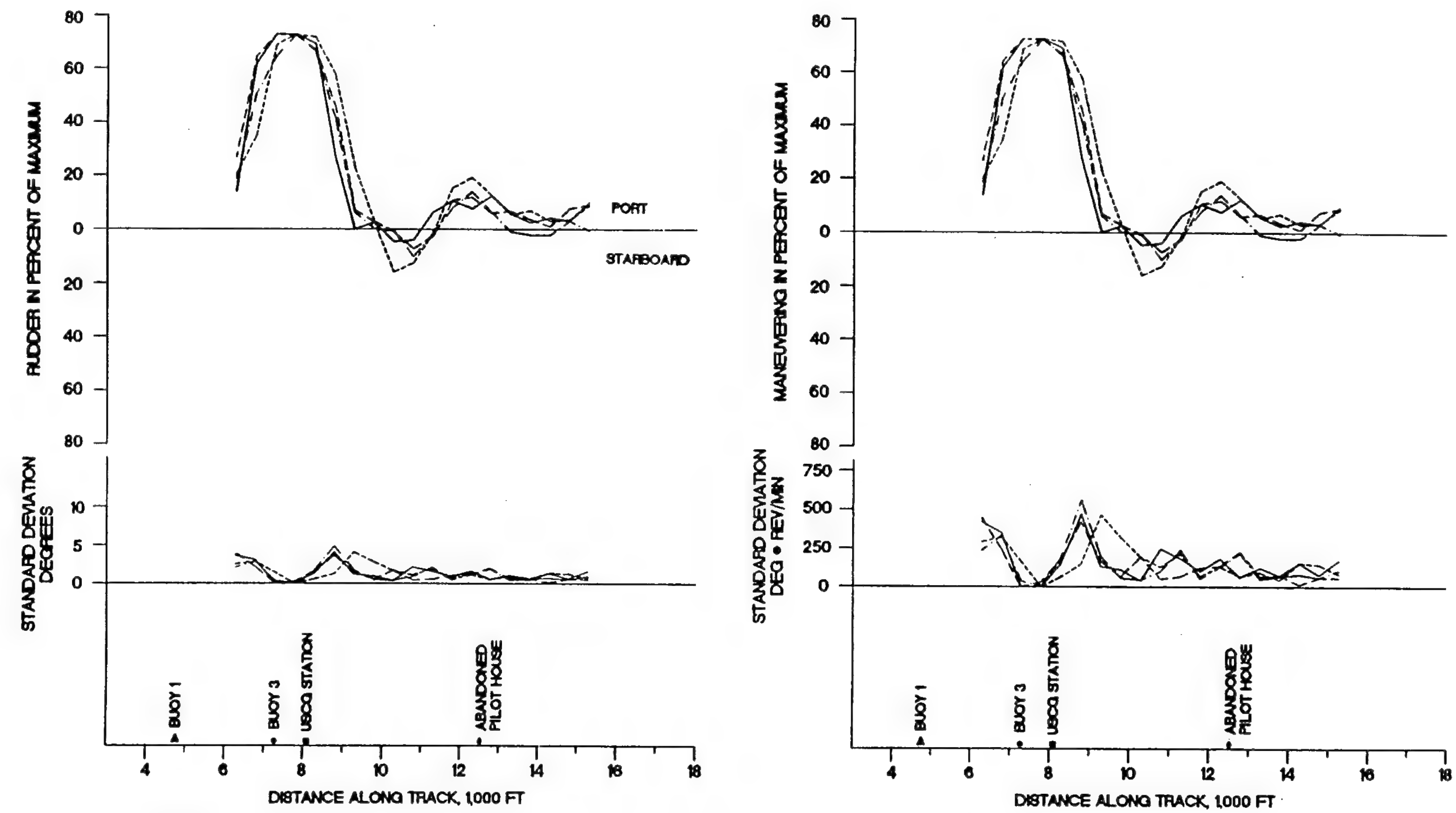


COMPOSITE TRACK PLOTS

OUTBOUND RUNS
HIGH RIVER DISCHARGE
675' X 45' CHANNEL
WES PILOTS


N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
OUTBOUND RUNS
HIGH RIVER DISCHARGE
750' X 45' CHANNEL
WES PILOTS


MEAN MINIMUM CHANNEL EDGE CLEARANCE
OUTBOUND RUNS - HIGH RIVER DISCHARGE
WES PILOTS
STARBOARD CLEARANCE IN FEET
PORT CLEARANCE IN FEET
DISTANCE ALONG TRACK, 1,000 FT
BUOY 1
BUOY 3
USCG STATION
ABANDONED PILOT HOUSE
LEGEND
600' X 40' CHANNEL
600' X 45' CHANNEL
675' X 45' CHANNEL
750' X 45' CHANNEL

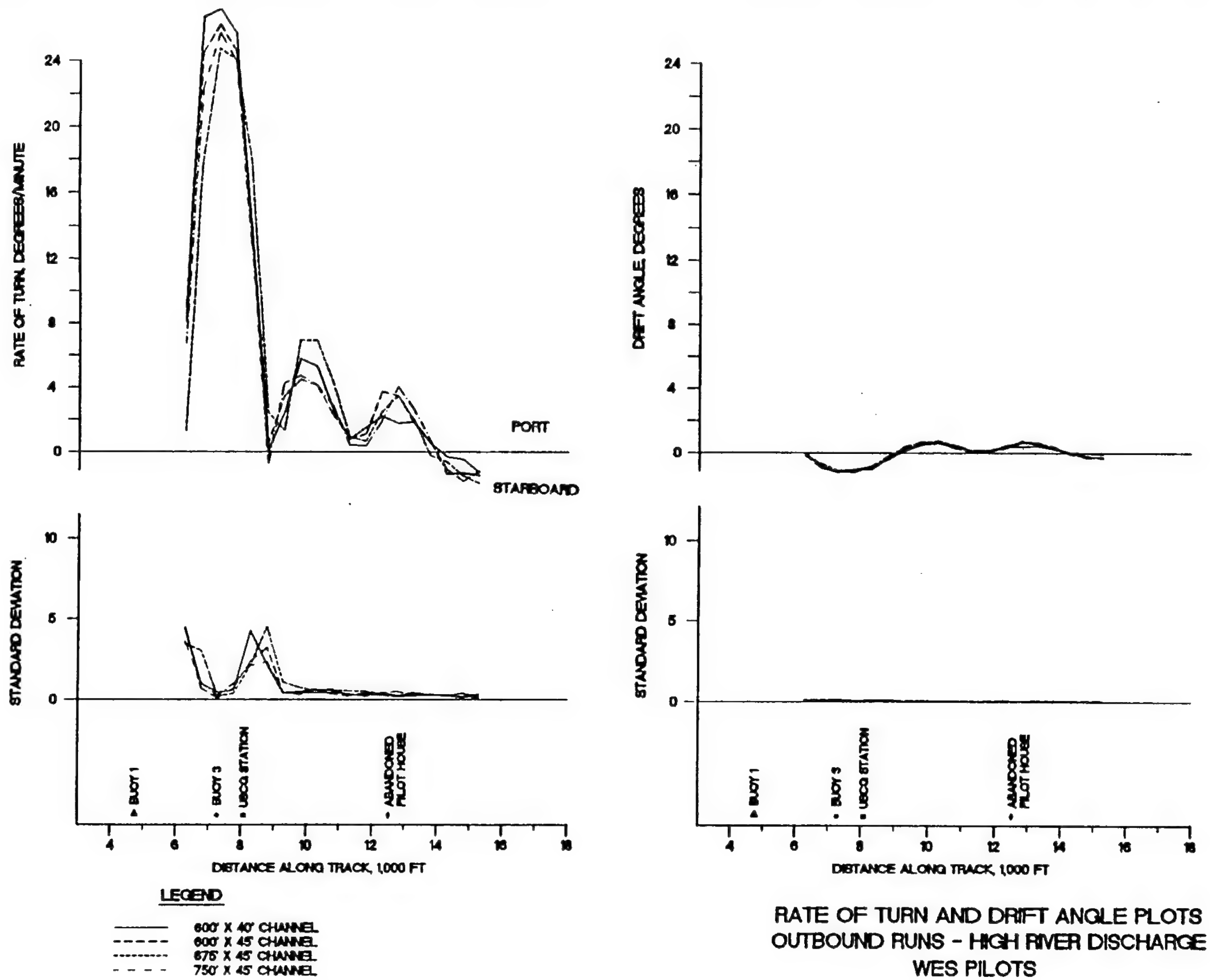


LEGEND

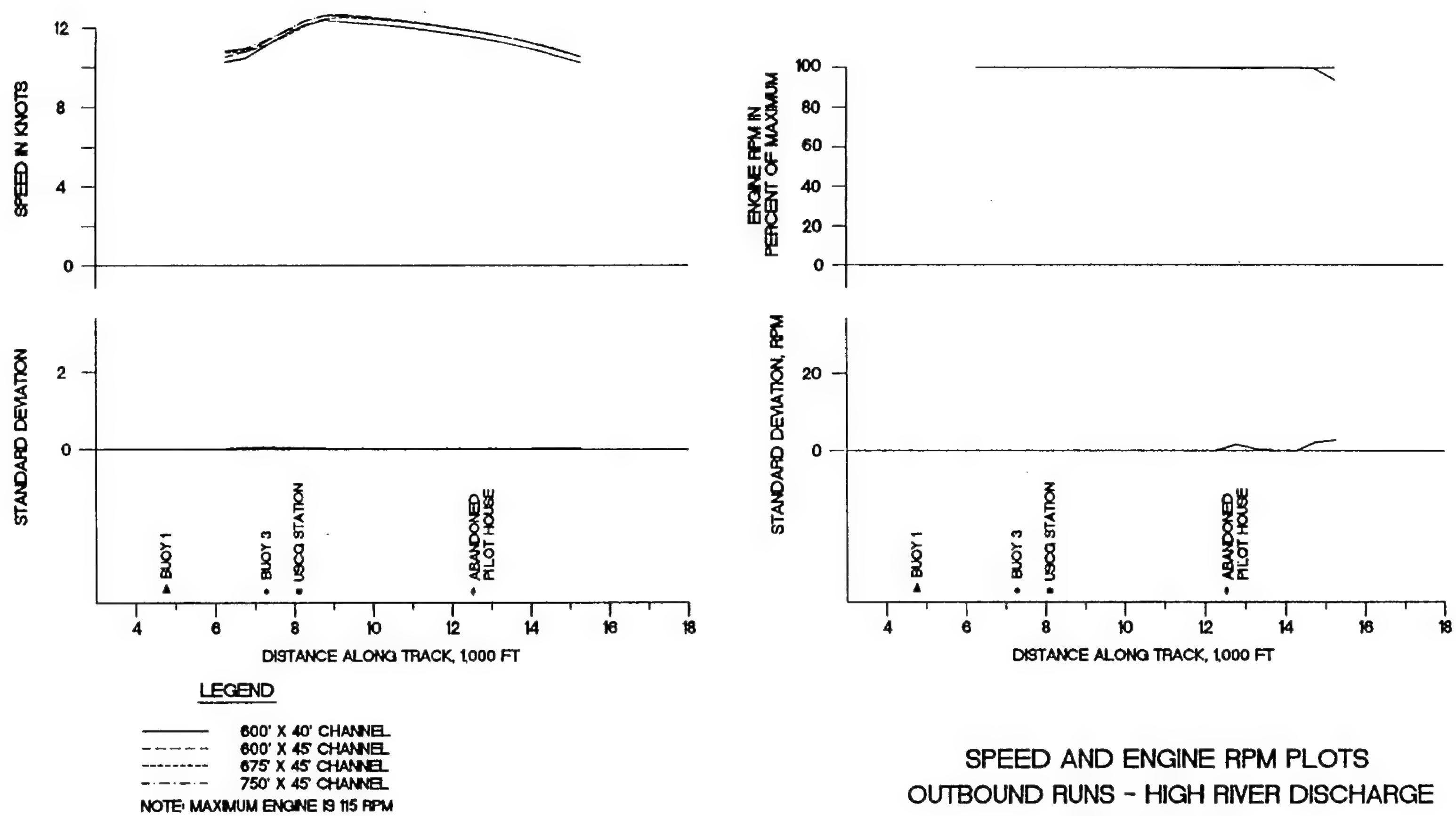
600' X 40' CHANNEL
600' X 45' CHANNEL
675' X 45' CHANNEL
750' X 45' CHANNEL

NOTE: MAXIMUM RUDDER IS 35 DEGREES
MAXIMUM ENGINE IS 115 RPM

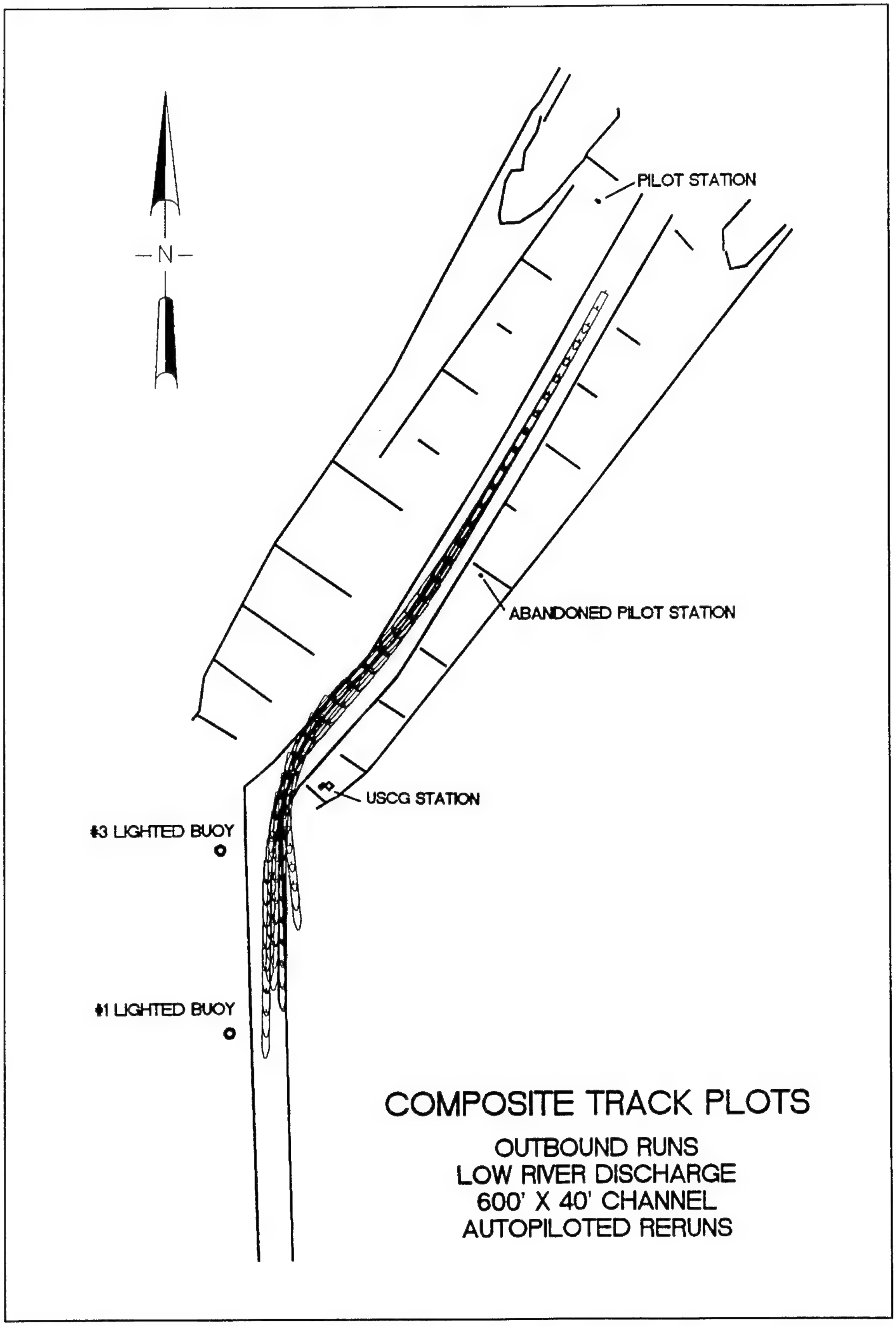
RUDDER AND MANEUVERING FACTOR PLOTS
OUTBOUND RUNS - HIGH RIVER DISCHARGE
WES PILOTS



RATE OF TURN AND DRIFT ANGLE PLOTS
OUTBOUND RUNS - HIGH RIVER DISCHARGE
WES PILOTS

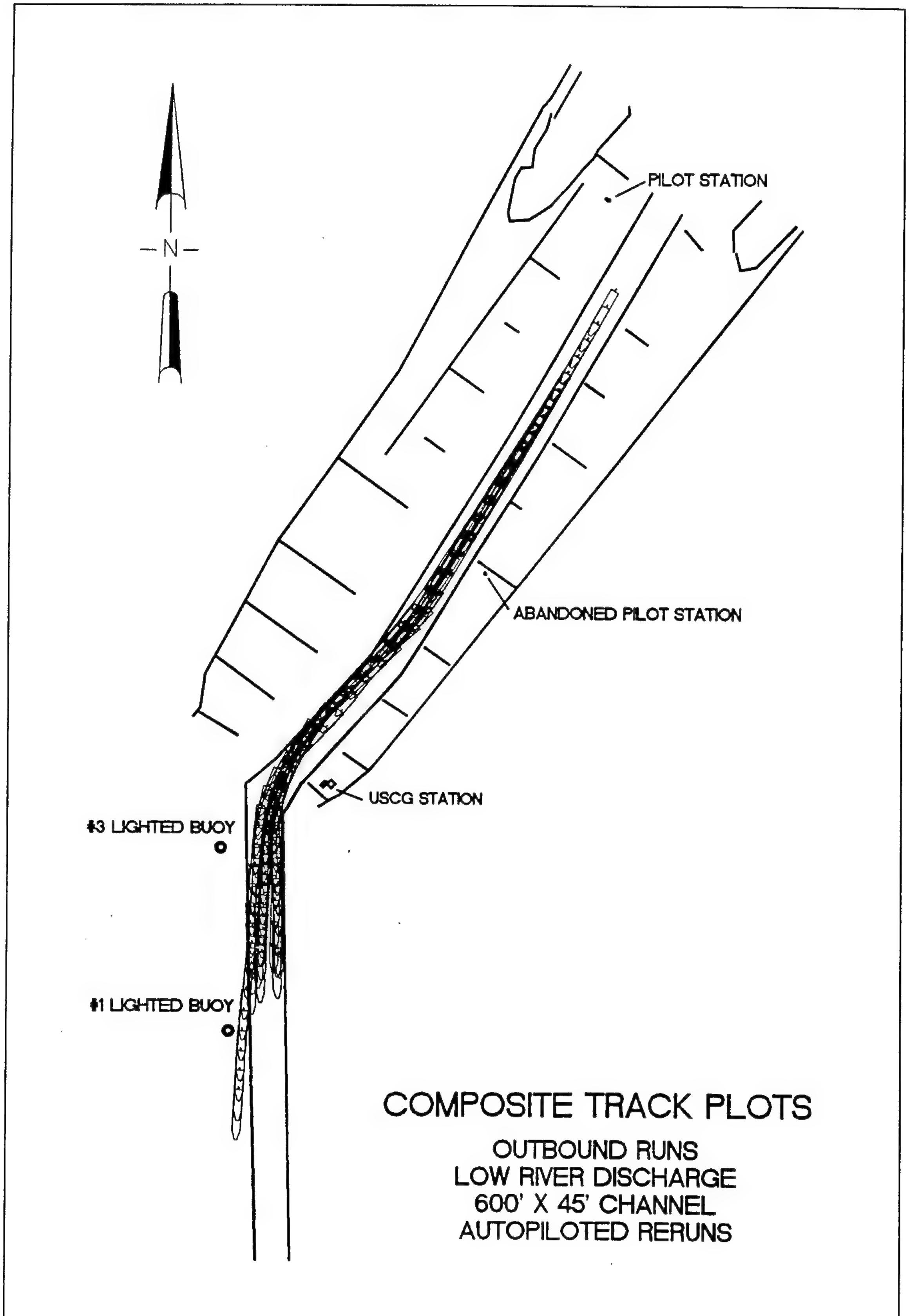


SPEED AND ENGINE RPM PLOTS
OUTBOUND RUNS - HIGH RIVER DISCHARGE
WES PILOTS



COMPOSITE TRACK PLOTS

OUTBOUND RUNS
LOW RIVER DISCHARGE
600' X 40' CHANNEL
AUTOPILOTED RERUNS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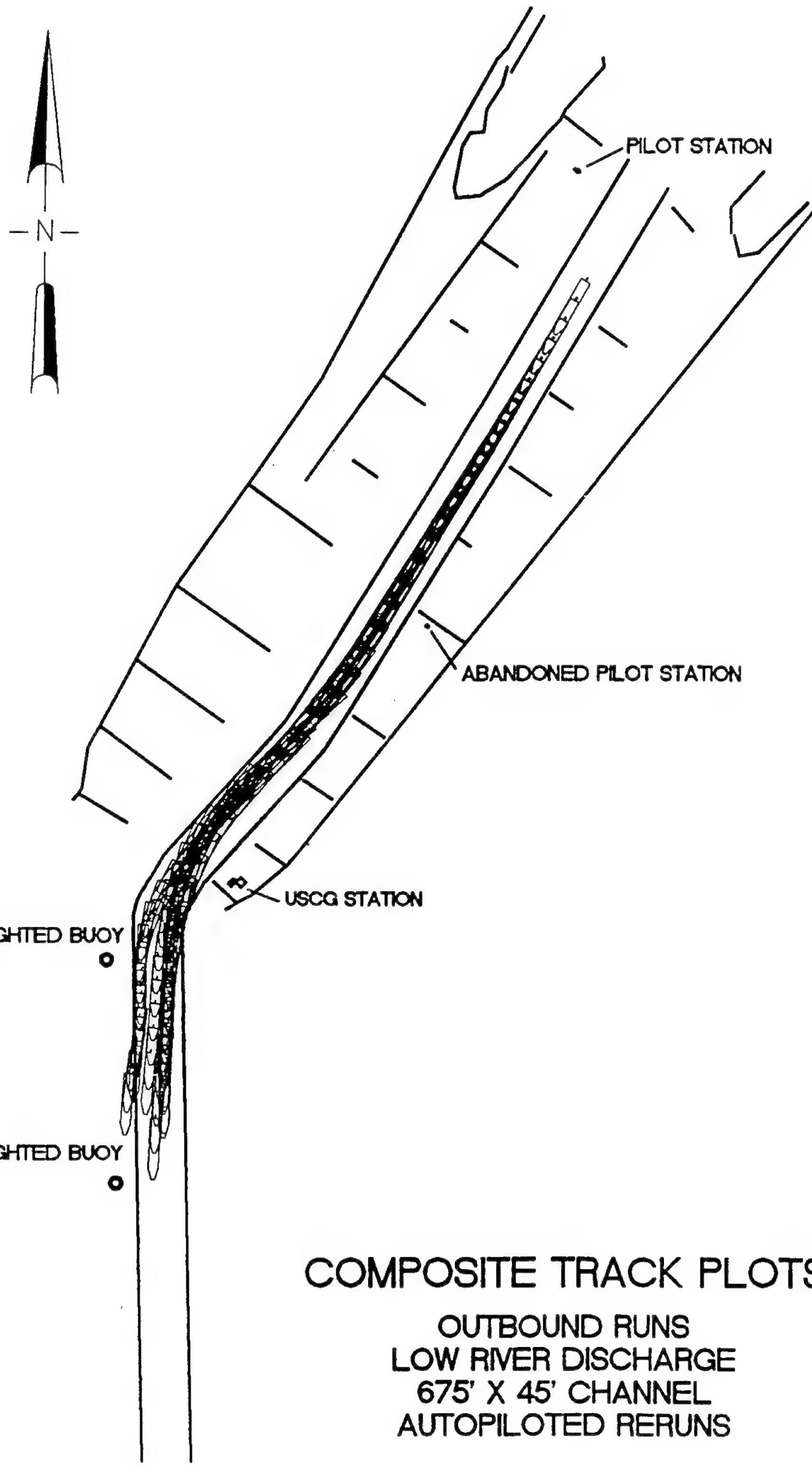
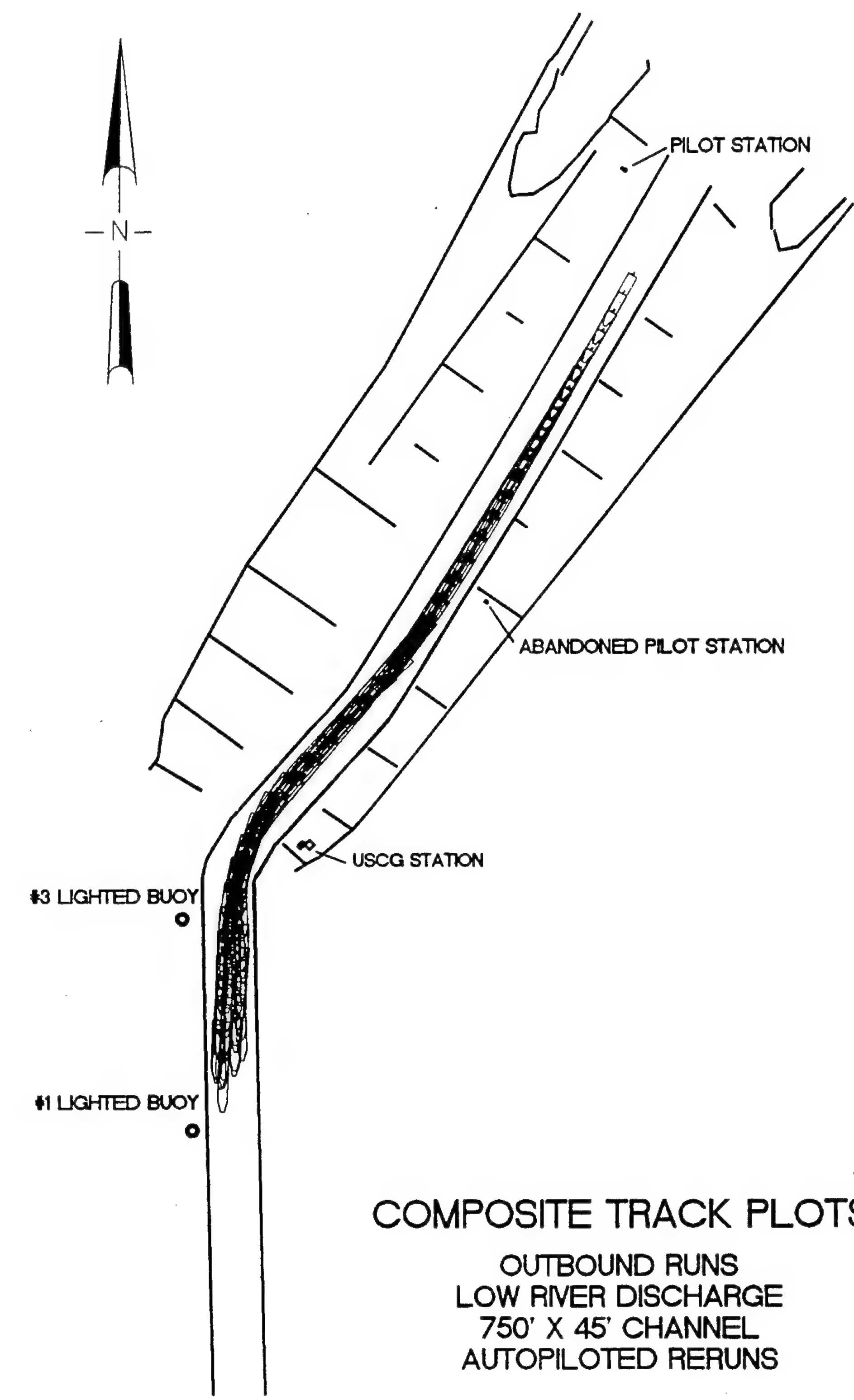
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
OUTBOUND RUNS
LOW RIVER DISCHARGE
600' X 45' CHANNEL
AUTOPILOTED RERUNS



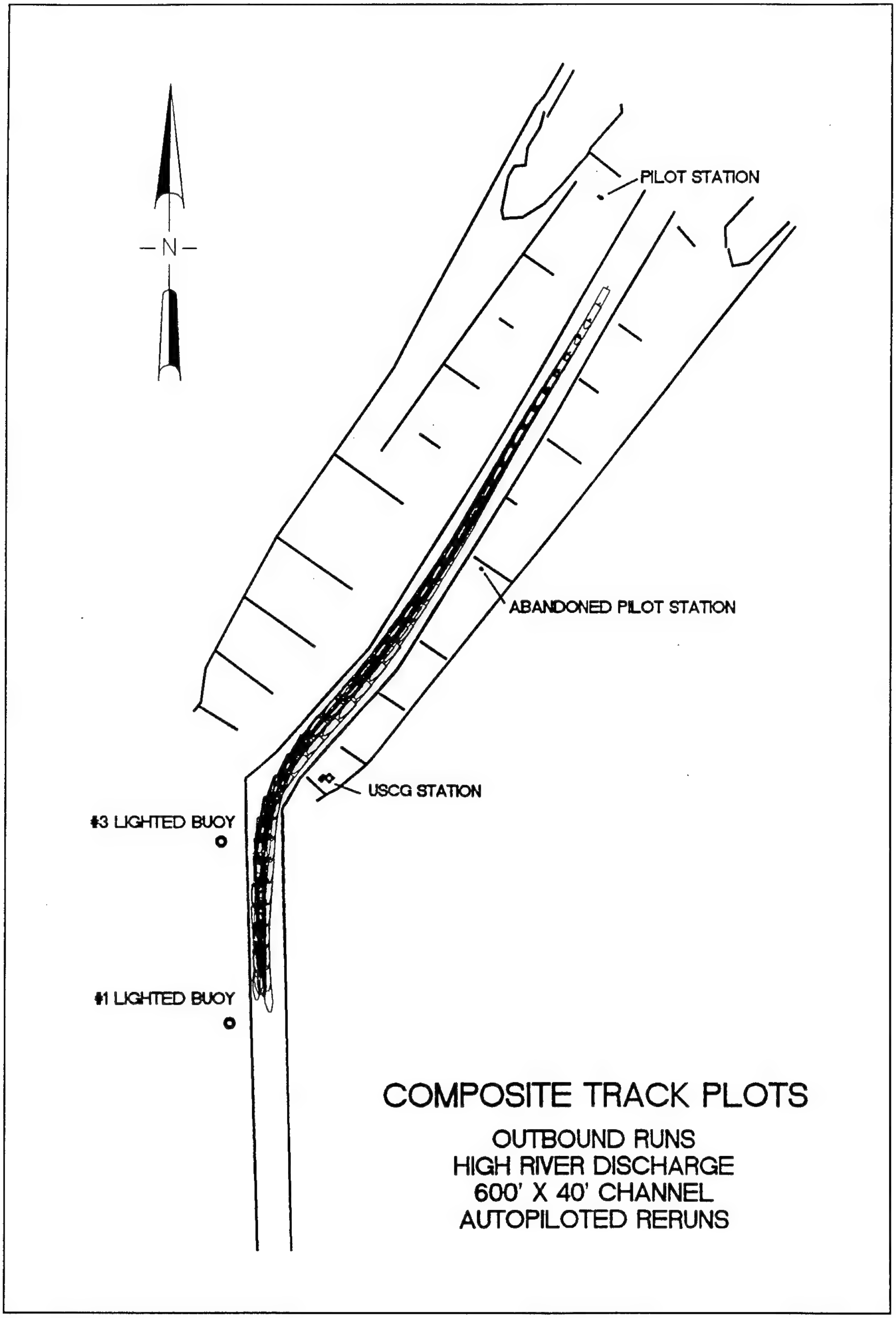
COMPOSITE TRACK PLOTS

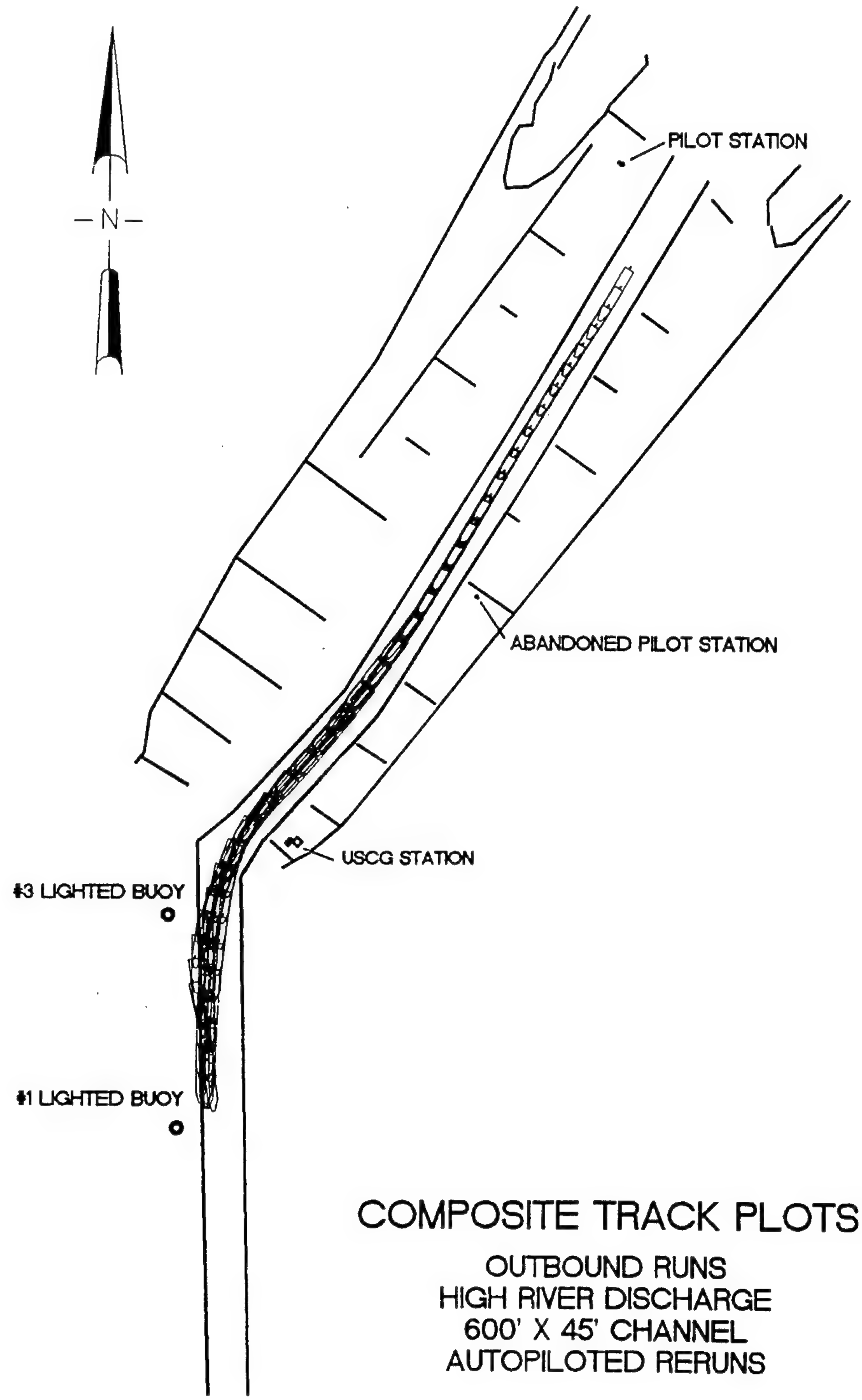
OUTBOUND RUNS
LOW RIVER DISCHARGE
675' X 45' CHANNEL
AUTOPILOTED RERUNS



COMPOSITE TRACK PLOTS

OUTBOUND RUNS
LOW RIVER DISCHARGE
750' X 45' CHANNEL
AUTOPILOTED RERUNS


N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
OUTBOUND RUNS
HIGH RIVER DISCHARGE
600' X 40' CHANNEL
AUTOPILOTED RERUNS



COMPOSITE TRACK PLOTS

OUTBOUND RUNS
HIGH RIVER DISCHARGE
600' X 45' CHANNEL
AUTOPILOTED RERUNS

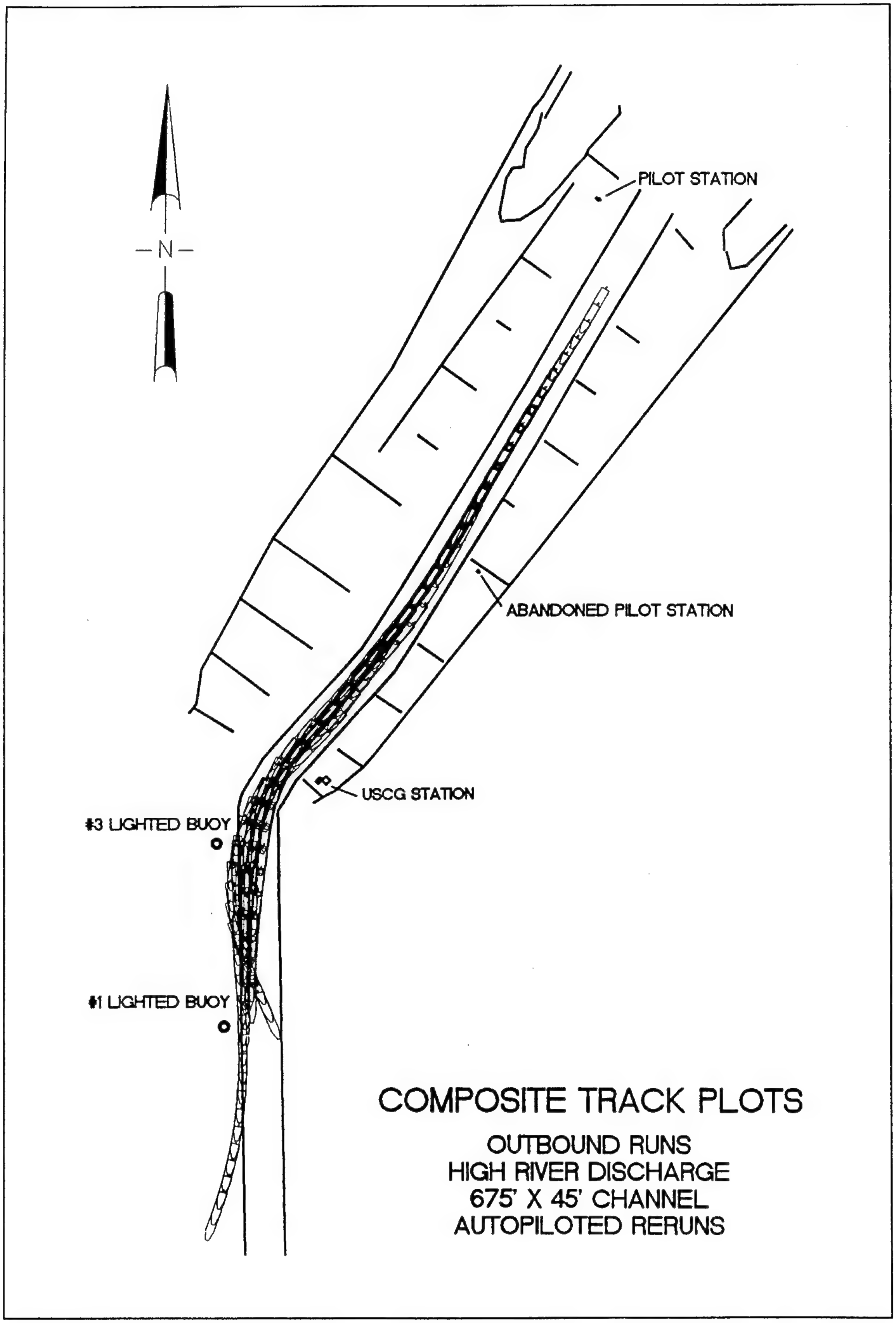
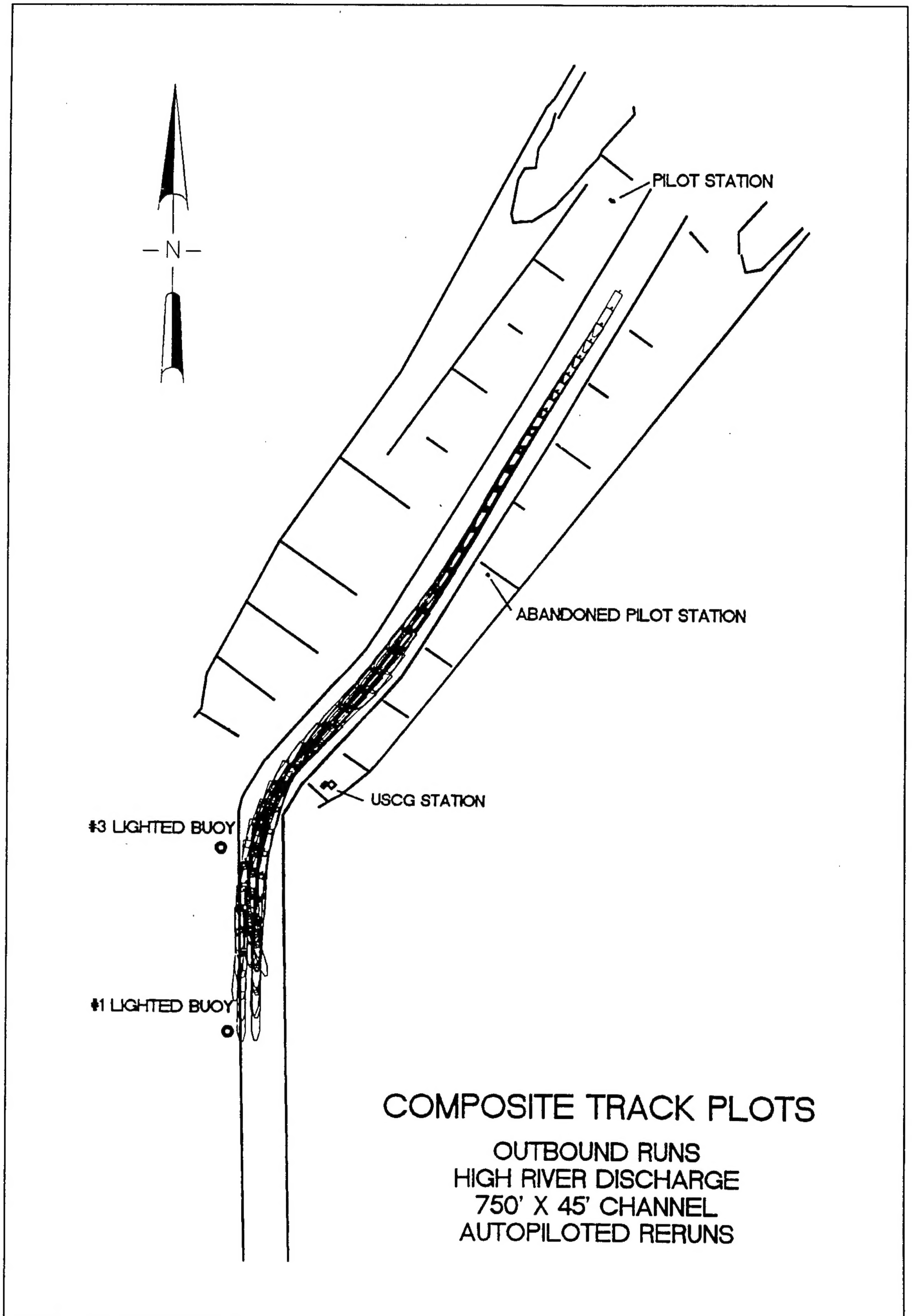

N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
OUTBOUND RUNS
HIGH RIVER DISCHARGE
675' X 45' CHANNEL
AUTOPILOTED RERUNS

Plate 68


N
PILOT STATION
ABANDONED PILOT STATION
USCG STATION
#3 LIGHTED BUOY
#1 LIGHTED BUOY
COMPOSITE TRACK PLOTS
OUTBOUND RUNS
HIGH RIVER DISCHARGE
750' X 45' CHANNEL
AUTOPILOTED RERUNS

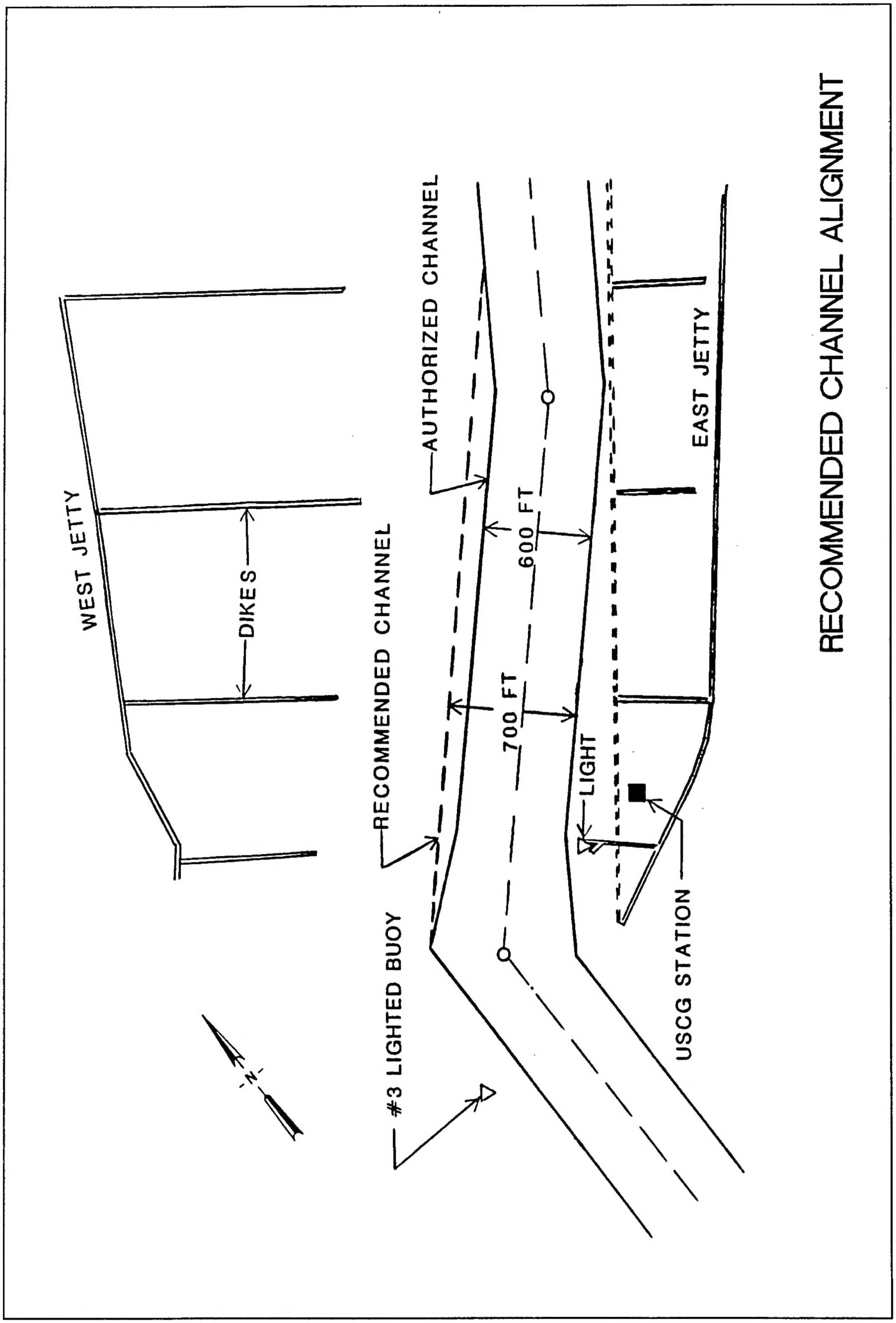

RECOMMENDED CHANNEL ALIGNMENT
WEST JETTY
DIKES
RECOMMENDED CHANNEL
AUTHORIZED CHANNEL
600 FT
700 FT
EAST JETTY
LIGHT
USCG STATION
#3 LIGHTED BUOY
N

Plate 70

REPORT DOCUMENTATION PAGE

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13. ABSTRACT *(Maximum 200 words)*

Southwest Pass, Mississippi River, is the main deep-draft navigational entrance into the Mississippi River and provides ocean access to the Ports of New Orleans and Baton Rouge, as well as other terminals servicing the many industries along the lower river. The pre-project channel was authorized at 600 ft wide and 40 ft deep, and proposed to be deepened to 45 ft to accommodate greater inbound tanker ships and outbound bulk grain carriers. The purpose of navigation ship simulation study was to determine the required channel width in the Southwest Pass to provide safe and efficient ship navigation, consistent with the minimum width to reduce dredging. To optimize the channel width, the then-existing channel was simulated and the results compared with several alternate channel widths including 600, 675, and 750 ft. The study included Mississippi River flows including a high flow of 1,300,000 cfs and a low of 640,000 cfs to bracket the normally expected range of velocities. Current velocities were developed using the TABS modeling systems. Only the entrance area of the Southwest Pass region was simulated and studied.

Pilots from the Louisiana Bar Pilots Association participated in the simulation validation and formal pilot testing of the channel alternatives. Tankers of 763-ft length and 125-ft beam loaded to 39-ft draft were used in the existing channel, and tankers of 840-ft length, 138-ft beam, and 44-ft draft were used in the proposed deepened entrance channel. Test results for

(Continued)

14. SUBJECT TERMS

Deepwater channel	River navigation	Ship simulation
Mathematical models	Ship channel	Southwest Pass
Mississippi River	Ship maneuvering	
Navigation channel design	Ship piloting	

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13. ABSTRACT (Concluded).

all piloted simulations were analyzed and included ship track plots and statistical analysis of key ship control parameters, such as ship rudder usage, ship speed, rate of turn, channel edge clearance, etc.

The simulation test results showed that the larger design ship will be able to safely navigate through the Southwest Pass entrance into the Mississippi River. Based on the study, it was recommended that the entrance channel width be increased from 600 ft to 700 ft for a short distance of about 3,000 ft on the western edge of the entrance channel.